THE SYSTEMATICS OF SOUTH AUSTRALIAN PRECAMBRIAN AND CAMBRIAN STROMATOLITES. PART 1

by W. V. PREISS*

Summary

The methods of field study and detailed morphological analysis using three-dimentional reconstructions and thin sections, developed by one Russian school, were applied to the abundant Precambrian and Cambrian stromatolites of the Adelaide Geosyncline. Although other schools either demand formal taxonomy for algal remains only, or use informal descriptive nomenclature of morphologies which they believe are determined entirely by environment, it is concluded that valid and consistent stromatolite form-taxa can be distinguished by these studies. The recognition of stratigraphically restricted taxa suggests biostratigraphic subdivision and intercontinental correlations.

New forms *Acaciella angepena*, *A. augusta*, *Baicalia burra* and *Boxonia melrosa*, and an indeterminate form of *Acaciella*, are described.

Introduction

Stromatolites are laminated structures formed in sediments, mostly carbonates, by the trapping and precipitation of sediment by mats of algae and bacteria. They are known throughout the sedimentary record, and are particularly abundant in otherwise unfossiliferous Precambrian sequences. This observed abundance and the diversity of forms have made stromatolites potentially useful as index fossils, provided that taxa can be defined which have stratigraphically restricted time-ranges. A group of Russian stromatolite specialists has been engaged in the systematic description and classification of stromatolites for the past fifteen years and their results stimulated this study of South Australian stromatolites in an attempt to apply biostratigraphic methods to the problems of the age and correlation of the Precambrian sequence in the Adelaide Geosyncline.

This paper is based on the systematics section of a thesis submitted for the degree of Ph.D., University of Adelaide. It is necessary here to briefly discuss the taxonomy of stromatolites and particularly to formalize several new taxa needed for subsequent discussions of biostratigraphy and palaeoecology. This paper, the first of three, will include an outline of previous studies, consideration of some taxonomic principles and problems, and descriptions of four new forms and one indeterminate form. The other parts will comprise descriptions of further forms and a discussion of the stratigraphic distribution of stromatolites. Stromatolite forms will be described in alphabetical order.

Background

This history of the early study of stromatolites was comprehensively reviewed by Maslov (1960). Although most researchers prior to 1914 sought an animal origin for these structures, for example Hall's *Cryptozoon* (1883) and Steinmann's *Gymnosolen* (1911), Walcott's (1914) discovery of filamentous microfossils in Precambrian stromatolites from the Belt Series of Montana paved the way for the understanding of stromatolite formation by algae.

Later workers clarified the role played by the algae. In particular, Black (1933) established that the algal mats of the Bahamas are polyspecific and that the mucilaginous filaments of the blue-green algae present trap detrital grains. Pia (1926) recognized the rock-building properties of modern blue-green algae. Algal filaments were also found by Bradley (1929) to occur in stromatolites of the Eocene Green River Formation of Wyoming.

In Australia, Mawson (1925) recognized stromatolites in the Flinders Ranges, and started a collection which was partly used in this study. During the 1930's fossil stromatolites were described by numerous authors, the most important being Young (1933a, 1933b, 1935), Fenton & Fenton (1931, 1933, 1936, 1937, 1939), Johnson (1937, 1940) and Maslov (1937a, 1937b, 1938, 1939a, 1939b). The work of others were reviewed by Maslov

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* Geological Survey, South Australian Department of Mines, Box 38, Rundle Street P.O., Adelaide 5000.

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(1960). Most of these authors tacitly accepted the validity of a formal binomial nomenclature for stromatolites.

Cloud (1942) was the first to question the validity of such a classification, arguing that stromatolites are built by associations of algal species. Similarly, Johnson (1966) has more recently rejected the use of this nomenclature, and suggested rather that only actual algal species should be named, if they are present. Nevertheless, Rezak (1957) found it useful to retain a binomial nomenclature and used the defined taxa successfully for intrabasinal correlation.

Since the controversy regarding the classification of stromatolites arose, at least three schools of thought have evolved. Firstly, a small group of Russian students (e.g. Vologdin 1962), like Johnson, considered that only actual algal remains can be validly named. But algae are very rarely preserved in Precambian stromatolites, and most of the micro-structures referred by Vologdin to fossil algae are very doubtfully of organic origin.

A second group rejects the concept of biological control over stromatolite morphology, and uses purely descriptive classifications to aid environmental interpretations. For example, Maslov (1960) used "generic" names such as *Collenia*, *Conophyton* and *Glebulella*, but he modified these by a series of descriptive Latin adjectives. Logan, Rezak & Ginsburg (1964) used symbols and formulae to describe various features of stromatolites, which they showed to be influenced by the local environment. Both Maslov's multinomial nomenclature and the variable descriptive formulae of Logan *et al.* tend to be cumbersome, and cannot in themselves describe all the useful characters of stromatolites. Some of the simpler formulae are, however, very useful in routine field descriptions. Hofmann (1969a) found difficulty in applying a binomial nomenclature to the stromatolites of the Gunflint Iron Formation, and later (Hofmann 1969b) discussed the significance of various characters of stromatolites, concluding that different morphologies are more likely to be environmentally than biologically controlled. Hoffman (1967, 1969) gave an outstanding example of the use of stromatolites in palaeocurrent determination.

The third school is a Russian group which describes and classifies stromatolites on the basis of morphology and microstructure, and uses them for biostratigraphy. Their first results were reported by Keller *et al.* (1960). Despite differences of emphasis today between different workers, all use a binomial nomenclature with the form taxa "group" (analogous to genus) and "form" (analogous to species). They have found that the time ranges of the defined taxa are restricted, and this allowed them to subdivide and correlate Late Precambrian sections throughout much of the USSR. The biostratigraphy was supported by numerous radiometric datings, both K–Ar determinations on glauconites and K–Ar, Rb–Sr and U–Th–Pb determinations on intrusives. The subdivision is as follows:

Cambrian
——————— 570 ± 10 m.y.
Vendian
——————— 680 ± 20 m.y.
Late Riphean
——————— 950 ± 50 m.y.
Middle Riphean
——————— 1,350 ± 50 m.y.
Early Riphean
——————— 1,600 ± 50 m.y.

The approach of this group was applied to Australian stromatolites, and it was found that many of the Russian taxa do occur here, in a similar order of succession (Glaessner, Preiss & Walter 1969; Preiss 1971). The resulting correlations with the dated Russian sequences were in agreement with most of the radiometric evidence available for the Australian Precambrian.

The successful use of stromatolites in biostratigraphy implies that their morphology is at least partly controlled by genetic characters of algae which evolve in time. The concept of biological control is supported by some studies of modern algal mats (Eardley 1938; Hommeril & Rioult 1965; Monty 1967). Each of these authors has shown the partial dependence of mat type on the predominating algal species present. This in turn affects the microstructure and lamina shape of the stromatolite, and indirectly, the gross morphology. Thus, deciding which characters are genetically determined and which are directly shaped by local environmental factors becomes the major difficulty in classifying stromatolites.

The Russian work of recent years has shown that it is mainly the columnar stromatolites which are of value in biostratigraphy. Only Komar (1966) has given a detailed account of laterally linked stromatolites but their usefulness has not been confirmed to the extent of that of columnar forms. In this study, atten-

Fig.1. DIAGNOSTIC TERMINOLOGY

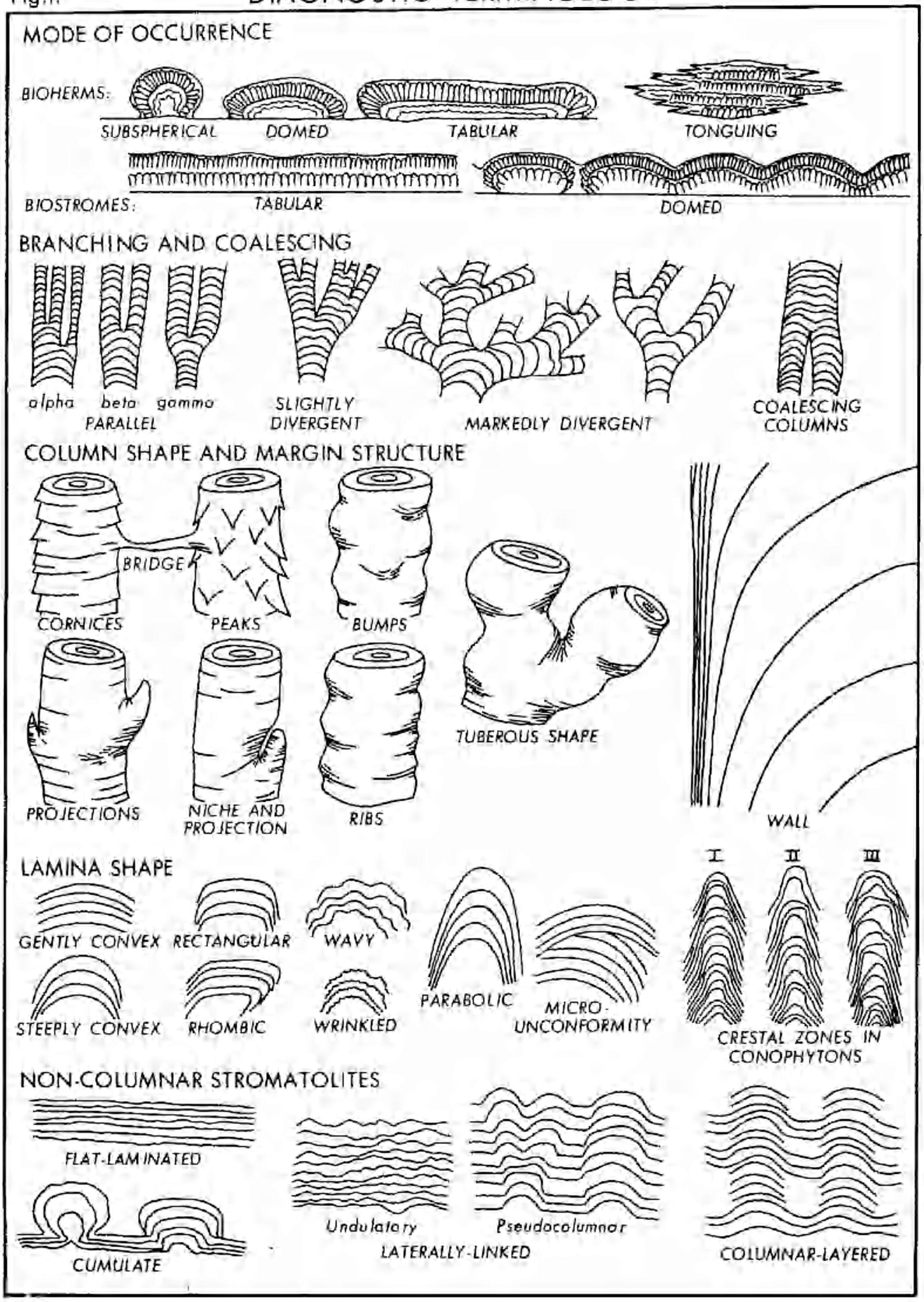

Fig. 1. Diagnostic terminology found useful in the description of stromatolites. The diagrams illustrate features discussed in the Appendix.

tion was also concentrated on columnar forms since these have the most characters allowing them to be classified. Therefore the binomial nomenclature has been applied only to these.

The terms used here to describe stromatolite characters, are largely based on translations of Russian terms, with minor alterations and additions. Most of the new terms introduced by Hofmann (1969b) are unnecessary from the point of view of this study. The diagnostic terminology proposed by Glaessner *et al.* (1969, Fig. 1) has been expanded (Fig. 1), and the terms used in the descriptions are defined in the glossary, Appendix I.

Taxonomy

In general the methods of stromatolite study and classification used by the Russians, Krylov (1963, 1967), Semikhatov (1962), Nuzhnov (1967) and Komar (1966) have been applied here, including binomial nomenclature. Although many of the group names have been accepted in palaeobotanical literature as genera, e.g. *Baicalia, Conophyton* and *Gymnosolen* by Andrews (1970), it is considered that retention of the terms *group* and *form* emphasizes the distinction between stromatolites as organo-sedimentary structures and actual fragmentary plant remains to which the terms *form genus* and *form species* may be applicable. While similar groups of characters are studied for each stromatolite, the relative taxonomic significance attached to any particular character may vary from taxon to taxon, depending on its diagnostic value. Mostly, *groups* are defined on the basis of gross morphology, column shape, branching and margin structure. Lamina shape and microstructure are frequently useful in the distinction of *forms*. But sometimes these features are diagnostic at group level—*Conophyton*, for example, is diagnosed by its lamina shape, and is characterized by particularly distinct lamination. *Baicalia* tends to be characterized by banded lamination, except where altered by diagenesis. Although the presence of a wall is a diagnostic difference between some groups, Walter (1970)[1] has described single stromatolites which are unwalled in their lower parts and walled at the top, in which case other features are diagnostic. No similar situation is known from South Australia.

It is considered unnecessary to use categories higher than the group, as Raaben (1964, 1969a, 1969b) has done. Her higher taxa are somewhat arbitrary and several alternative ones could be proposed, but all are equally questionable. On the other hand, the *variety* as a subdivision of the form is useful in cases where finer subdivisions can be made, and is therefore retained for *Conophyton garganicum*.

It could be argued that a single name would be sufficient to characterize a particular stromatolite, but the value of a binomial nomenclature is that it indicates real similarities and differences between various forms. Thus groups contain one or more forms which all share a number of characters considered diagnostic for that group. Forms are distinguished within a group whenever there are sufficient gross or microstructural differences. But the essential comparison between closely related forms would be lost without a binomial nomenclature.

The chief difficulty in the taxonomy of stromatolites is the isolation of discrete character combinations, where intergradation is common. Thus, subjective choice may be required in some cases. Where the morphology remains uniform throughout a particular occurrence, a single name can easily be applied, but if there is variation within the occurrence, the definition must be broadened. Whether or not the morphology of a stromatolite from another occurrence falls within this range of variation is difficult to decide. Conversely, if a significantly different morphology occurs as a discrete portion of an occurrence, is this to be classified separately? Examples of stromatolites with a broad range of variation are *Tungussia etina* and *Linella munyallina*. Both of these show a spectrum of intergrading branching types and column shapes, even within single outcrops, so that the range of variation between specimens of different areas lies within the range of variation in one locality, and these are therefore included in the one form.

It has been found that many characters overlap, and distinctions must be made even at group level on the most commonly occurring expression, i.e. the mode, of each character. This is especially true of branching. *Boxonia* is characterized by α-parallel and some β-parallel branching, while γ-parallel is rare. In *Gymnosolen* γ-parallel predominates, but not to the total exclusion of the other types. Similarly, there is overlap between the branching styles of *Baicalia* (the forms of which show a tremen-

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[1] Unpublished Ph.D. thesis, University of Adelaide.

dous variation of branching, as shown by Krylov 1967) and that of *Tungussia*. But while *Baicalia* has predominantly slightly to moderately divergent branching, in *Tungussia* markedly divergent branching predominates.

Although it is often easy to recognize groups on the basis of even limited reconstructions and longitudinal sections, the identification of forms is more difficult and subjective. Forms are distinguished on minor features of column morphology, lamina shape, or microstructure. Microstructure is the most difficult character to use, partly because different types intergrade to some extent and partly because it is so easily altered by diagenesis. The distinctive lamination of *Conophyton* is somewhat exceptional, and is amenable to statistical analysis. Although Raaben (1969a) has attempted similar studies on *Inzeria* and Semikhatov, Komar & Serebryakov (1970) have measured the sizes of clots and pellets in *Boxonia*, it is uncertain whether or not the structures measured are primary.

The laminae of most South Australian columnar branching stromatolites are too diffuse and variable to allow a detailed statistical study, although the well-preserved representatives of the banded microstructure of *Baicalia burra* might be amenable.

Stromatolites can be classified only on the basis of combinations of characters, and, as Walter (1970, unpublished) has also concluded, the classificatory significance of characters must vary to some extent from taxon to taxon. The classification has been found empirically to be useful in that the resulting taxa are temporally restricted. The question arises as to the fundamental meaning of these taxa, and why they are so restricted. Several possibilities exist:

(1) Each form is built by a particular association of algal species, and forms change as the content of the associations changes.

(2) Each form is built by a dominant algal species, in association with other species that have little effect on stromatolite morphology.

(3) The environment, and not the algal composition, entirely controls the stromatolite morphology.

If (3) were true, we should expect a temporal restriction of forms only if the environment has systematically evolved in time. It is difficult to see how local factors such as current activity or sediment accumulation which could conceivably control stromatolite morphology, can exhibit continent-wide, if not world-wide, unidirectional change. On these grounds, this possibility must at present be rejected. If (1) were true, we could expect the morphology to change gradually as the overall algal composition changes, one species replacing another in the association. On the other hand, if one species controls the morphology, a rapid change would be expected. At present, it is not possible to tell which of (1) and (2) is correct and possibly both apply; the first possibility may explain the intergradations sometimes observed between taxa, when classification becomes difficult.

Although Hofmann (1969b) regarded *Conophyton* as apart from other stromatolites, recent work has shown that conophytons possibly intergrade with columnar branching forms such as *Baicalia* (Shapovalova 1968). Similarly Bertrand (1968) described intergradations of *Conophyton* and branched forms. While the taxonomic significance of these changing morphologies and their relationship to environmental factors has not been fully determined, it is clear that *Conophyton* is not fundamentally different from other stromatolites.

It is concluded that stromatolites must be defined on combinations of characters, the significance of each of which may vary in different taxa. The fact that some taxa have much broader ranges of variation than others results from the necessity of grouping intergrading morphologies present in single stromatolite occurrences.

Methods

Stromatolites were studied both in the field and in the laboratory, but field observations were often limited by outcrop conditions and lichen cover on rock surfaces. Where possible, the mode of occurrence, column shape and arrangement and branching were observed in order to gain an impression of the total variability.

The variable nature of stromatolites necessitates sampling of sufficient material to determine the modal expressions of characters present. Depending on the size of columns, large specimens weighing from 4-70 kg were collected, and the relative position and orientation were noted. Ideally, bioherm centres and margins were both sampled.

The diagnostic gross features of columnar stromatolites can only be determined from a three-dimensional view of the structure. This is achieved by the method of "graphical reconstruction" described by Krylov (1963). A series of 10 to 15 serial longitudinal slabs 2 to 6 mm wide were cut on an oil-cooled 60 cm diamond saw with a saw cut about 2 mm wide. The columns were outlined in pencil on the slabs and traced on to a block diagram framework on tracing paper, each longitudinal section being parallel to the front face of the block. The reconstructions were retraced with shading to show surface morphology and finally redrafted by stippling.

Lamina shape, margin structure and microstructure were studied in large, longitudinal, thin sections, up to 20 cm long. Their thickness varies with the nature of the rock, but in general they must be thicker than petrological sections to preserve the distinctness of the structures. Carbonates were mostly identified by staining with Alizarin Red S, but were frequently checked by X-ray diffraction powder photographs.

Systematics

For each group from which forms are described, a diagnosis, a list of the known constituent forms and the stratigraphic and geographic distributions are presented. Forms are diagnosed only if described here for the first time. Descriptions are given under the headings *mode of occurrence, column shape and arrangement, branching, margin structure, lamina shape* and *microstructure*. The interspace sediments and the nature of secondary alteration are also described since they provide important clues to the depositional environment and diagenetic history.

The distribution of forms refers to both their geographic distributions and to the rock-stratigraphic units (Thomson *et al.* 1964) in which they occur. Reference is made for each locality and stratigraphic unit to the relevant geological sheet (either 1:63,360 or 1:250,000 map sheets, Geological Atlas of South Australia).

It was found convenient (Preiss 1971) to subdivide the Adelaidean into two time units: the Early Adelaidean, represented by all sediments up to the pre-tillite unconformity, and the Late Adelaidean, represented by sediments from the base of the lower tillite to the base of the Cambrian. This subdivision reflects both a climatic change and a major change in stromatolite assemblages. Ages of stromatolites will be referred to as Early or Late Adelaidean, but the probable correlations with the subdivisions of the Riphean will be noted in each case.

Type specimens are kept in the Department of Geology and Mineralogy, University of Adelaide, catalogued under numbers prefixed by S.

Group ACACIELLA Walter

Walter has supplied the group name *Acaciella* and the following diagnosis.

"*Type Form: Acaciella australica* (*Cryptozoon australicum* Howchin 1914).

Diagnosis: Nearly straight, parallel or radially arranged sub-cylindrical columns with α-, β- and rarely γ-parallel and very slightly divergent multiple branching. On column margins are numerous low bumps and occasional small cornices and peaks; small areas of wall occur infrequently. Laminae dominantly are rectangular, rhombic or gently domed and are not markedly wavy or wrinkled; the microstructure is streaky."

Content: Acaciella australica Walter, *A. angepena* f. nov. and *A. augusta* f. nov.

Age and Distribution: Adelaidean to Early Cambrian; Loves Creek Member of the Bitter Springs Formation, Central Aust.; the Lower Cambrian of S. Aust.; the Wundowie Limestone and Brighton Limestone equivalent, Umberatana Group, S. Aust. and as erratics in the lower (Sturtian) glacials, S. Aust.

Acaciella angepena f. nov.

FIGS. 2, 10, 11a

Material: Forty-seven specimens from nine localities.

Holotype: S460 (Figs. 2a, 10c), Lower Cambrian, 1 km south of Angepena H.S., Northern Flinders Ranges.

Name: After the type locality.

Diagnosis: *Acaciella* with vertical or radially arranged columns or pseudocolumns, which may branch upwards from either flat-laminated or small cumulate stromatolites. Columns may branch upwards into minute, irregular columns. Bridging is extremely common. Microstructure is regularly banded, with thin continuous laminae. Vermiform microstructure may be developed.

Description

Mode of occurrence: Cambrian stromatolites were studied in outcrop only in the Angepena area, where lenticular stromatolite beds consist of closely spaced ellipsoidal and domed bioherms 3 to 50 m wide. These overlie flaggy, laminated, dark grey limestones with irregular erosional contacts. Cumulate or pseudocolumnar stromatolite individuals commence growth upon the erosional highs, and pass up into radially arranged or parallel short columns with very numerous bridges. At bioherm margins, columns and pseudocolumns become horizontal, and laminae are deflexed parallel to the overhanging sides of the bioherm, so that here growth actually proceeded downwards (Fig. 10a & b, showing longitudinal sections of a bioherm margin). Where adjacent bioherms become contiguous, they are overlain by a domed biostromal layer of columnar, pseudocolumnar and columnar-layered stromatolites, similar to those of the bioherm. At the edge of a stromatolite bed, the terminal bioherm has an abrupt vertical margin and the laminae bend downwards only slightly. The surrounding sediment of dark lime mud accumulated synchronously with stromatolite growth, and occasional algal laminae are intercalated with it; the bioherm probably never had more than 10 cm of relief over the surrounding sediment surface. Also, there is evidence of contemporaneous compaction of the lime mud the bioherm rests upon (Fig. 10c); the lower layers of the surrounding muds are depressed, while the upper ones simply abut against and cover the bioherm.

Column Shape and Arrangement: Column shape is highly variable in single bioherms, mainly due to different degrees of coalescing and bridging. The structures vary from laterally linked pseudocolumns with some discrete small cumuli (Fig. 10d) to frequently bridged and coalescing columns (Fig. 11a), to discrete, parallel subcylindrical columns (Figs. 2d, f, g; 10f). The latter chiefly make up Mawson's (1925) collection from Italowie Gorge. In all specimens where columns are reasonably discrete, they are smooth to slightly bumpy, sometimes with pointed terminations (Fig. 2b, j), while others branch into minute columns 1 to 3 mm wide. Columns are commonly less than 1 cm diam., but broad, cumulate columns up to 10 cm diam. have been observed. Transverse sections of columns are round, rounded polygonal or lobate (Fig. 2d, f, g). Columns may be vertical or radially arranged, especially on the margins of contiguous bioherms. Dolomitization of interspaces frequently obscures the original margins of the minute columns so that their shape cannot be accurately determined.

Branching: Branching is most commonly α- or β-parallel, occasionally γ-parallel. Columns frequently branch into narrower columns which do not regain the former diameter. Some branches are in the form of thin pointed projections (Fig. 2j). At bioherm margins, branching may remain parallel (Fig. 10c) or become radial (Fig. 10b), but here the stromatolites are largely pseudocolumnar.

Margin Structure: Column margins are rarely preserved intact. Commonly they are corroded by dolomite rhombs, if the interspaces are dolomitized; otherwise very fine stylolites may be developed. Bridging is extremely common in all specimens except those from Mawson's collection from Italowie Gorge, in which the columns are mostly discrete. These also have the smoothest margins, with only slight, occasional bumps and ribs. Columns are always unwalled, the laminae thinning only slightly near the column margin. Laminae may slightly overhang the margin, but long peaks and cornices are absent.

Lamina Shape: Fig. 8a illustrates common lamina shapes; most are gently convex. Of 101 lamina measured, 69% have height to diameter ratios (h/d) beneath 0.2 and 0.4, only 7% have ratios greater than 0.6 (Fig. 9a). Laminae are smoothly domed, without sharp changes in shape from lamina to lamina. A few of Mawson's specimens from Italowie have wavy laminae, of wavelength 3 to 10 mm, amplitude 1 to 3 mm (Fig. 10f).

Microstructure: Microstructure in all specimens is regularly, thinly banded, with continuous laminae of uniform thickness across a column width. In most specimens there is little contrast between dark and light laminae, except in the amount of organic pigment. Some specimens, especially from Angepena, have irregularly tubular, sinuous, anastomosing, vermiform sparry patches, 0.05 to 0.1 mm thick and up to 0.6 mm long, crossing the dark laminae. Dark laminae, varying in thickness from 0.03 to 0.07 mm, consist of xenotopic calcite of grain size varying from 0.003 to 0.01 mm, stained with grey organic pigment, but in some specimens, subhedral dolomite rhombs of grain size 0.01 to 0.02 mm are interspersed. Minor subangular quartz silt may be present. Individual laminae are continuous, and of constant thickness across the column width, but may be markedly wavy. In specimens with vermiform microstructure, dark laminae are generally thicker, up to 0.3 mm, but remnants of finer lamination are often preserved. The boundaries of the sparry patches are often irregular and their orientation varies from perpendicular to gently inclined to the lamination, but is commonly at a high angle to it. The vermiform microstructure may be consistently developed preferentially on one side of a column. Transverse sections of the tubules are found to elongated, irregularly oriented and anastomosing. The tubules may be interpreted as algal borings in the fine, lime mud laminae, but not the whole sediment was affected, since homogeneous and bored laminae occur side by side. This fact also makes it unlikely that they are casts of actual algal filaments. The distribution of borings on one side of columns may be environmentally determined. Bathurst (1966, p. 20) illustrated a sequence of events involved in boring by algae; if the process were stopped at stage (2), and the borings infilled with sparry calcite, a structure similar to the vermiform microstructure of *A. angepena* would result. Light laminae are 0.03 to 0.1 mm thick, frequently indistinct, but continuous across a column width. They are especially poorly differentiated in specimens with vermiform microstructure, where the tubules may pass across the light-dark lamina boundaries. Light laminae consist of xenotopic calcite, often with interlocking crystals 0.015 to 0.03 mm in diameter. Subhedral to euhedral 0.01 mm dolomite rhombs are scattered throughout the light laminae in some specimens.

Interspaces: Interspaces are filled either with altered micrite or fine sandy and silty micrite. Specimens from Italowie (Mawson's collection) have very narrow interspaces filled with sparse, angular quartz silt, supported by a micrite matrix (Fig. 10f), sometimes extensively dolomitized, with inequigranular hypidiotopic dolomite ranging in grain size from 0.005 to 0.1 mm. Extremely finely disseminated haematite may be present in interspaces. Stromatolites from Angepena also have sandy interspaces, but these are more frequently interrupted by bridging laminae. Subangular to subrounded quartz grains vary in diameter from 0.08 to 0.5 mm, and may be partially or wholly replaced by calcite. Ooids and small intraclasts occur very rarely.

Secondary Alteration: Dolomitization is common in all specimens, and is probably of late diagenetic origin. Within columns, rhombs postdate the vermiform microstructure and have also formed in the micrite of interspaces, and in places, interspaces may be totally dolomitized. Here sparry calcite occurs as irregular patches between dolomite rhombs perhaps filling a secondary porosity. The grain size and density of dolomite rhombs decrease markedly across the column margins; perhaps interspaces were originally more porous, to cause the preferential dolomitization (in Fig. 10c note the dark calcite columns and the white, dolomitic interspaces). Stylolites may follow column margins, or may be grossly cross-cutting. Haematite dispersed through carbonate is probably secondary. In Italowie specimens, it is concentrated in interspaces which pass into fine stylolites. Minute irregular calcite veins cut the whole rock, apparently predating the major dolomitization. Large patches of coarse sparry calcite are bounded by markedly lobate fine stylolites, suggesting their origin as solution cavities.

Comparisons

In gross morphology (mode of occurrence, column shape, branching and margin structure) the stromatolites from Italowie are similar to *Acaciella* Walter. Columns are less discrete in other areas, due to frequent bridging and coalescing, but their columnar portions are similar to those of Italowie specimens. Microstructures are uniform, except for the local vermiform structure interpreted as algal boring. *Madiganites mawsoni* Walter, from the Middle Cambrian Jay Creek Limestone of the Amadeus Basin, also has vermiform microstructure, but here the tubules are more consistently developed, and are complexly intertwined, the intervening micritic areas being reduced to clots. The gross form of *Madiganites mawsoni* is similar to some *Acaciella angepena* in having numerous irregular frequently bridged columns and pseudocolumns; however, it lacks the subcylindrical, parallel branching, discrete columns found at Italowie. *Acaciella angepena* resembles *Vetella uschbasica* Krylov in having evenly banded lamination and wide columns branching into narrow columns, but has ragged column margins and lacks the wall of *V. uschbasica*. *Ilicta composita* Sidorov is similar in also possessing vermiform microstructure, but is distinguished by its very smooth, walled, columns. At this stage it is difficult to be certain of the content of the form *Acaciella angepena*. Despite some variation of column shape (specimens from Italowie have predominantly subcylindrical, discrete columns, while those from Angepena have numerous bridges and less regular column margins, all the specimens studied are included in the one form, since these column morphologies intergrade and the microstructures remain constant. The stromatolites are assigned to the group *Acaciella* on

Fig.2

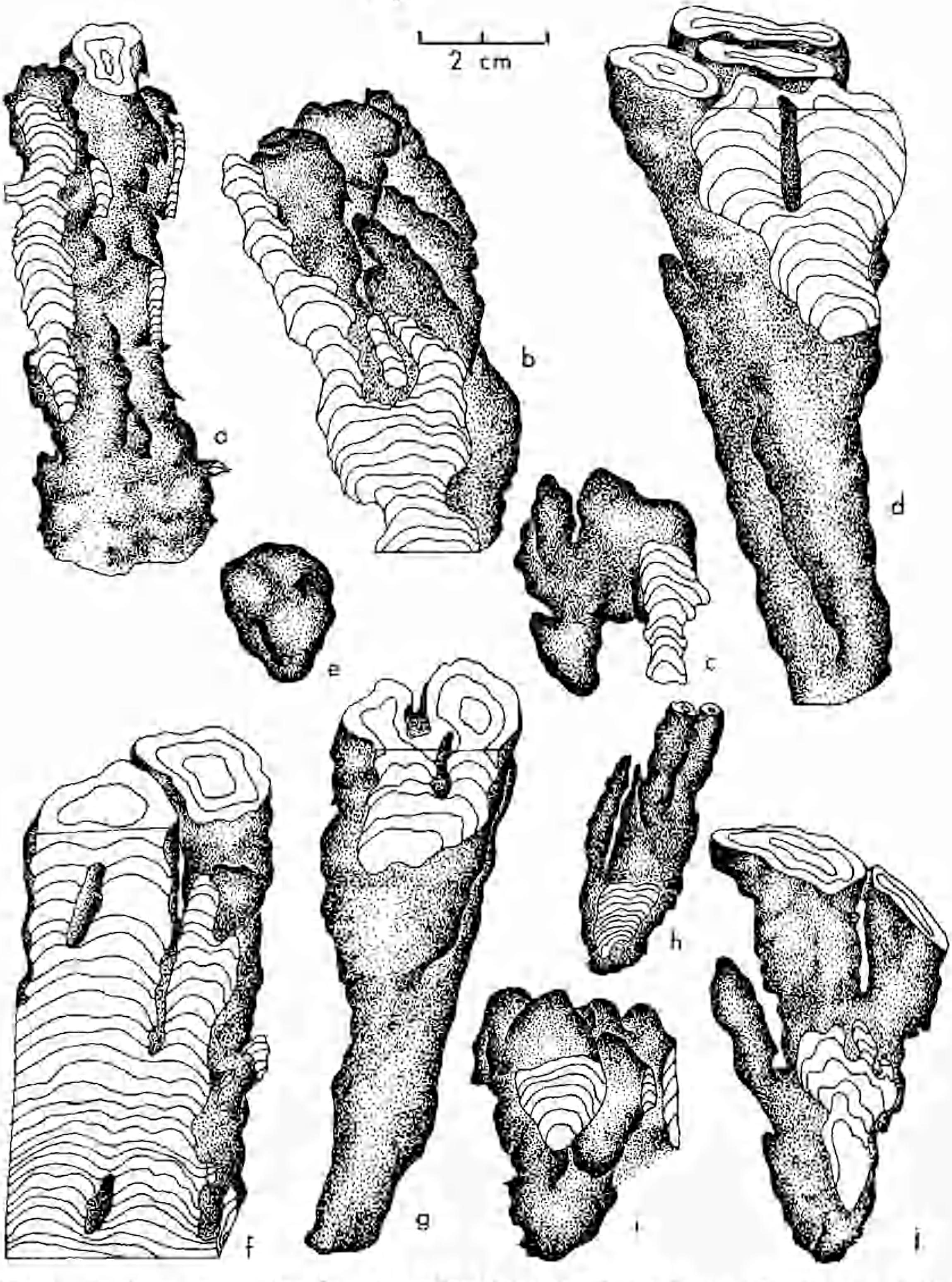

Fig. 2. *Acaciella angepena*, from Lower Cambrian Limestones, Flinders Ranges. (a)—Holotype, S460, 1 km S. of Angepena H.S.; (b)—S458, 1 km S. of Angepena H.S.; (c), (e) & (i)—S459, 1 km S. of Angepena H.S.; (d) & (g)—S8, 4.8 km W. of Italowie Gorge (collected by Sir Douglas Mawson); (f)—S44, 4.8 km W. of Italowie Gorge (collected by Sir Douglas Mawson); (h)—Probable *A. angepena*, near Old Wirrealpa (collected by Mr. P. G. Haslett); (j)—Possible *A. angepena*, 4.8 km W. of Italowie Gorge.

the basis of gross morphology. They are differentiated from other forms of the group by their thin, continuously banded microstructures and by frequent development of bridges and pseudocolumns. The very narrow, minute columns into which broader columns branch are absent in other forms.

A ferruginous specimen from Old Wirrealpa is problematical. Its dark laminae are strongly haematitic, the haematite being in part distributed into minute dendrites. The small columns branch from basal cumuli, the interspaces being filled with recrystallized biomicrite (hyolithids, sponge spicules, archaeocyathan and brachiopod fragments may be recognized). Although the gross morphology resembles that of *Acaciella angepena* (Fig. 2h), the extremely regular lamination is atypical of stromatolites, and the possibility of an inorganic origin for the structure cannot be excluded.

Distribution: Widespread in the dark limestones of the Lower Cambrian at Angepena, Old Wirrealpa, near Point Well, at Mern Merna, Beltana Hill, Chace Range, near Narina H.S., Moro Springs south of Balcanoona, and 4.6 km west of Italowie Gorge; Flinders Ranges, South Australia. (COPLEY and PARACHILNA 1:250,000 map sheet areas.)

Age: Early Cambrian.

Acaciella augusta f. nov.

FIGS. 3a-m, 11d-f, 12

Material: Thirteen specimens from two localities plus eight specimens of uncertain identification from a further two localities.

Holotype: S401 (Figs 3c, e; 12c), Brighton Limestone equivalent, Depot Creek, Southern Flinders Ranges.

Name: After the city of Port Augusta, 32 km south of the type occurrence.

Diagnosis: *Acaciella* with extremely frequent coalescing and bridging of columns at all levels, and with broad and narrow columns closely associated. Column margins bear short ribs, low bumps and short cornices. Laminae are gently to moderately steeply convex or rectangluar, and of distinct, regularly streaky microstructure.

Description

Mode of Occurrence: The stromatolites form lenticular and tonguing bioherms (Fig. 12a) varying in thickness from 3 m to 50 m, and extending laterally for up to nearly 2 km, intercalated at varying stratigraphic levels within the Brighton Limestone equivalent. Most commonly, growth commences on a substrate of ooid and intraclast grainstones, as laterally linked stromatolites, up to 3 m thick; these gradually develop interspaces to form broad, bridging and coalescing columns (Fig. 11d). At various levels, these columns branch into narrower columns 1 to 3 cm wide, frequently with parallel basal and slightly divergent upper branches (Fig. 12c). Occasionally, narrow columns arise directly from an undulatory or flat-laminated base (Fig. 11f). Columns repeatedly alternate with continuous undulatory or flat-laminated stromatolites, which commonly intertongue with the adjacent sediment; they apparently mark periods of reduced influx of coarse sediment. At bioherm margins, columns become slightly inclined. Rarely, there are hemispherical bioherms with columns strongly inclined at their margins.

Column Shape and Arrangement: Basal columns are up to 20 cm wide, of irregular shape, with frequent coalescing and bridging. Their margins are frequently inclined, although laminae remain subhorizontal. The narrow columns are 1 to 3 cm wide, and up to 10 cm long between branches (Figs. 3a-j; 12b-d). Transverse sections are round, rounded polygonal, elongated, or complexly lobate. At least some of the elongation is of tectonic origin. Columns are straight or gently curved, with slight swellings and constrictions (Fig. 3a-j); a few are short and narrow, and terminate their growth after a few centimetres (Fig. 3e). Coalescing is so frequent that almost all columns are interconnected; one specimen contains numerous irregular, short, frequently bridged and coalescing columns.

Branching: Branching is frequent at all levels, and generally multiple (Fig. 3a-j). Broad basal columns divide by α-parallel branching into narrower columns, which frequently branch again at intervals of less than 10 cm; this branching is usually α- or β-parallel, occasionally γ-parallel, or slightly divergent (Fig. 3c-e, g). Near points of coalescing, branching tends to be more irregular; gamma-parallel or divergently branched columns approach each other and coalesce (Fig. 3d).

Margin Structure: The lateral surfaces of all columns bear relatively low bumps, short discontinuous ribs, and a few peaks and cornices (Fig. 3a-j). In places, bridges, varying from delicate bridges only one or two laminae thick to massive, thick bridges (Fig. 3g), are very frequent; in other places, columns remain relatively unaffected by bridging throughout most of their length. Columns are unwalled, and between bridges and cornices their margins are relatively smooth. Depending on the degree of convexity, laminae approach the margin at various angles.

Lamina Shape: Lamina shape varies according to column diameter; narrow columns have moderately convex, or sometimes steeply convex, laminae, h/d greater than 0.6 being rare. Broad columns have very gently convex to rectangular laminae (Fig. 8b). Of all laminae measured, 70% have h/d between 0.2 and 0.6 (Fig. 9b). Laminae are most frequently smooth, but sometimes broadly wavy, especially before branching. Laminae frequently become doubly-crested before branching (Fig. 12b-d), but the interspace so formed may be bridged over, in which case the column resumes its former growth pattern.

Microstructure: In the best preserved specimens, distinct, regular light and dark (green) laminae, and in places macrolaminae up to 4 mm thick, alternate, forming a regular streaky microstructure (Fig. 12c). *Dark laminae*, varying in thickness from 0.05 mm to 2 mm, are smooth to gently wavy, occasionally wrinkled, and have parallel upper and lower boundaries. Single laminae have relatively constant thickness across the column width, but frequently lens out. They consist chiefly of hypidiotopic to idiotopic dolomite, of grain size ranging from 0.005 to 0.02 mm. The crystals are equidimensional, commonly euhedral, and stained pale green, which gives the laminae their colour. Dolomite crystals are densely packed in the dark laminae, leaving only occasional irregular undolomitized patches, consisting of xenotopic calcite, ranging in grain size from 0.003 to 0.01 mm. *Light laminae* vary in thickness from 0.07 to 2 mm, single laminae having constant thickness. They are sparsely dolomitized, and consist of xenotopic to hypidiotipic calcite, varying from 0.01 to 0.02 mm in grain size, with scattered euhedral dolomite rhombs, 0.005 to 0.04 mm long. Laminae are frequently grouped into broad macrolaminae, up to 4 mm thick, in which very thin, lenticular, either light or dark laminae predominate. In places, laminae are slightly wrinkled, or draped over underlying irregularities; in one case laminae are domed over lenses of sparry calcite, probably open space fillings (Fig. 11e). In a few places small scour structures up to 2 mm deep are cut into the tops of dark laminae. Occasional euhedral to subhedral reddish brown limonite grains of 0.01 to 0.02 mm diameter (possible pseudomorphs after pyrite) occur in both lamina types.

Interspaces: The distance between columns varies from 1 to 10 mm. Interspaces are filled with banded limestone, layers of micrite 1 to 6 mm thick alternating with thicker intervals of partially dolomitized intramicrite. Laminae in the interspace commonly abut against the column margins, having accumulated after the growth of that part of the column (Fig. 12c). The micrite laminae, consisting of xenotopic calcite of grain size varying from 0.003 to 0.01 mm, are frequently silty, and slightly graded, generally with sharp upper boundaries, and are overlain by matrix-supported intramicrites and some oomicrites. This sediment may originally have been more porous, as it is extensively dolomitized; the dolomite is of similar texture to that in columns. All remnant calcite is recrystallized to a hypidiotopic sparry mosaic; no micrite matrix remains. Alternatively, this calcite may represent infilling of voids left by dolomitization. Intraclasts, which may be preserved as undolomitized micrite, or entirely idiotopic dolomite, are from 1 to 10 mm long, and up to 1 mm thick, and may represent eroded fragments of algal mat. Strongly recrystallized dolomitized oolites are occasionally present. Intraclasts, which commonly lie at a high angle to the bedding, may have fine grained laminae draped over them. Coarse sediment influx was periodic; columns may have had up to 2 cm of relief over the interspace sediment or a bridge, then the interspaces were filled rapidly with intraclasts and finer calcareous sediment. During periods of relative quiescence, lime mud accumulated to form thin layers. In some specimens, bridging is very frequent, so that there never was more than about a centimetre of relief.

Secondary Alteration: Little is preserved of the primary difference between the light and the dark (green) laminae, which now differ in the extent of dolomitization. The dolomite is equigranular, idiotopic, and probably secondary, although a detrital origin cannot be ruled out. If the dolomite originated by replacement of calcite, the preferential dolomitization of dark laminae may indicate that they were originally more porous. Small irregular patches of coarsely crystalline sparry calcite within both columns and interspaces post-date dolomitization, and are associated with fine calcite veins. Stylolites are very rare, being restricted to a few which are concordant with the lamination or column margins. The green staining of dolomite crystals oxidizes under subaerial weathering to form finely disseminated limonite, which may be concentrated along column margins or stylolites. Columns are commonly slightly flattened parallel to an axial plane cleavage, which is better developed south of Depot Creek and at Mundallio Creek. The cleavage is an irregular fracture which passes around, not through, stromatolite columns and is commonly expressed as stylolites in the carbonate rocks. A specimen from Mundallio Creek contains light laminae with prominent radiating structures; these consist of dolomite crystals aligned in rows almost perpendicular to the lamination (Fig. 12d), and may represent a dolomitized, earlier acicular texture. In specimens from the Wundowie Limestone (Wundowie Bore and Copley), column margins have been almost completely removed by stylolites, leading to uncertainty of identification (Fig. 3k, l & m).

Comparisons

The predominantly parallel branching (α-parallel at base, then β- or rarely γ-parallel) and almost total absence of a wall, identify the stromatolites as *Acaciella*.

Acaciella augusta is distinguished from *A. australica* by the rarity of discrete, broad, basal columns, by its mode of occurrence (lenticular and tonguing bioherms instead of tabular and domed biostromes), by its extremely frequent coalescing and bridging, and by its very distinct microstructure. The mode of occurrence and microstructure also distinguish it from *A. angepena*. *A. augusta* has many wavy, sometimes lenticular laminae, and prominent macrolaminae, the dark laminae being preferentially dolomitized. *A. augusta* is very similar in gross morphology to *Eucapsiphora paradisa* Cloud & Semikhatov, from the Paradise Creek Formation near Mt. Isa, N.W. Queensland. *E. paradisa* is difficult to distinguish on the basis of the published description, but apparently has a patchy wall.

Specimens of poorly preserved stromatolites from the Wundowie Limestone near Copley and Wundowie Bore, originally tentatively identified as *Linella munyallina* (Preiss unpubl.) are better assigned to *Acaciella augusta* on the basis of column shape, branching and microstructure. Where column margins are not removed by stylolites, they are unwalled.

Distribution: Brighton Limestone, Depot Creek and Mundallio Creek, Southern Flinders Ranges, and possibly the Wundowie Limestone near Copley and Wundowie Bore, Northern Flinders Ranges (PORT AUGUSTA and COPLEY 1:250,000 map sheet areas).

Age: Late Adelaidean, correlated with the Late Riphean of the USSR.

Acaciella form indet.

(FIGS. 3n-q; 11b, c)

Material: Two specimens from one locality.

Description

Mode of Occurrence: Both stromatolite specimens are erratic boulders in the lower (Sturtian) glacials; their provenance is unknown.

Column Shape and Arrangement: One specimen (S509), consists of pseudocolumns and frequently bridged columns, oriented subparallel to slightly radiating, and passing laterally into flat-laminated stromatolites (Fig. 11c). The other specimen (S539) consists of rather smooth, erect, parallel, cylindrical, discrete columns, 1-5 cm wide. Transverse sections are round or rounded polygonal (Fig. 3n-p).

Branching: Branching is commonly α- or β-parallel; columns either retain their width or widen gradually before branching. Axes of branching columns may be very slightly divergent (Fig. 11b). Specimen S539 shows only dichotomous branching, but S509 has some multiple, α-parallel branching.

Margin Structure: S539 has a rather smooth margin structure, with low bumps and a few very short peaks and overhanging laminae (Fig. 3n-p). There is no wall; laminae simply terminate, without appreciable thinning, at the column margins. Bridges are extremely frequent in S509, but otherwise column margins are similar to S539. Few columns in S509 are entirely discrete.

Lamina Shape: All laminae are gently convex (Fig. 8c), h/d never exceeding 0.5, and 84% of laminae measured have h/d between 0.2 and 0.4 (Fig. 9c). Laminae are smoothly curved, rarely rectangular, and without wrinkles or sharp flexures. Occasionally laminae are slightly wavy, and before branching always develop multiple crests (Fig. 11b, c). Laminae are not normally deflexed at the column margins.

Microstructure: Microstructure consists of very smooth or broadly wavy, light and dark, dolomitic, striated to banded, laminae. There is little contrast between laminae. *Dark laminae* are 0.05 to 0.5 mm thick, and commonly pinch and swell slightly across the column, and in places they are lenticular, but otherwise, they have smooth, parallel boundaries. They consist

Fig. 3

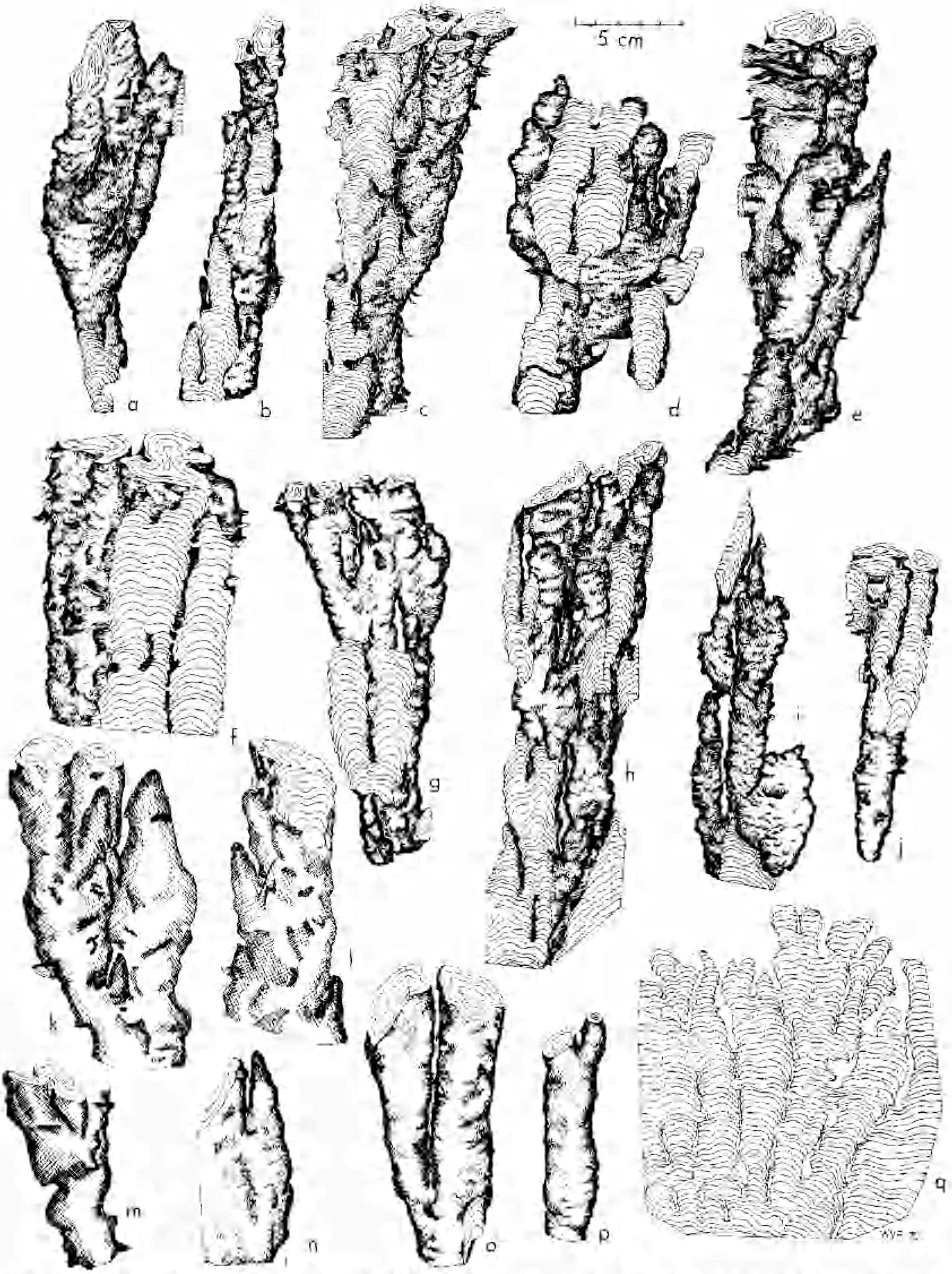

Fig. 3. (a)-(j); *Acaciella augusta*, Brighton Limestone equivalent, Umberatana Group, Flinders Ranges: (a), (b), (d) & (i)—S404, Depot Creek, Southern Flinders Ranges; (c) & (e)—Holotype, S401, Depot Creek; (f)—S538, Mundallio Creek, Southern Flinders Ranges; (g) & (h)—S396, Depot Creek; (j)—S537, Depot Creek; (k), (l) & (m)—Possible *A. augusta*, Wundowie Limestone Member, Wundowie Bore, Northern Flinders Ranges; (n), (o) & (p)—S539, *Acaciella* f. indet. from an erratic in the Sturtian glacials, N.E. of the Enorama Diapir; (q)—S509, *Acaciella* f. indet., from the same locality. Sketch traced from a thin section.

of pale grey stained hypidiotopic dolomite of grain size varying from 0.003 to 0.015 mm. *Light laminae* vary in thickness from 0.05 to 1.0 mm, generally with little change across a column, thinning only slightly towards column margins. They consist of hypidiotopic to idiotopic transparent, unstained dolomite of grain size varying from 0.015 to 0.06 mm. Very characteristic of S539 is the presence of very fine, limonite-rich solution surfaces, concordant with the laminae. Although these are probably stylolites, surfaces with little or no wrinkling, which follow the fine-scale structure of laminae exactly, are especially common (Fig. 11b). In places these are only about 0.5 mm apart, and light laminae may be separated by them, without intervening dark laminae.

Interspaces: Interspace sediment is completely dolomitized, consisting of equigranular, idiotopic dolomite of grain size ranging from 0.01 to 0.05 mm. There is little contrast between columns and interspaces, but small amounts of subangular quartz silt are present in the interspaces. Fragments of slightly darker stained dolomite, of similar texture to the matrix, probably represent original intraclasts. The nature of the matrix cannot be determined, but the sparsity of intraclasts suggests that these were mud supported. Intraclasts are better preserved in S509.

Secondary Alteration: Dolomitization of the stromatolites and interspaces is clearly secondary, as indicated by the general idiotopic, equigranular texture, and poor preservation of the finest structures. Stylolites are of at least two generations; the earliest stylolites are almost perfectly concordant, without lobes or wrinkles: these possibly predate the dolomite euhedra, which in places cut into them, and certainly predate a relatively coarse grained dolomite vein (grain size up to 0.1 mm). The vein is itself cut by more pronounced, slightly discordant stylolites. Occasionaly cross-cutting stylolites cut interspaces and columns, some following column margins. Dolomitization almost certainly predates the erosion and deposition of the clasts into the glacial sediments.

Comparisons

The straight, chiefly α- to β-parallel branching unwalled columns allow assignment to the group *Acaciella*. They are clearly distinguished from *Acaciella augusta* by the discrete, rather smooth, more cylindrical columns; although bridging and coalescing occur in S509, this specimen is considered to represent the basal part of the stromatolite bed. The distinct, subcylindrical columns with relatively smooth margins and gently convex laminae are similar to *A. australica* Walter, but the specimens are inadequate for identification.

Distribution: As clasts in the lower (Sturtian) glacials, on the flanks of Enorama Diapir, 6.4 km North of Oraparinna H.S., Central Flinders Ranges (PARACHILNA 1:250,000 map sheet area).

Age: Probably Adelaidean, but not younger than the Sturtian glacials.

Group BAICALIA Krylov

Baicalia Krylov 1963: 64. Semikhatov 1962: 198. Komar 1966: 82. Krylov 1967: 25. Nuzhnov 1967: 135. Cloud & Semikhatov 1969: 1035.

Type Form: *Baicalia baicalica* (Maslov) Krylov, from the Uluntuy Suite of the Pribaikalye [based on *Collenia baicalica* Maslov 1937a: 287].

Diagnosis: Tuberous, bumpy, swelling and constricting, parallel to markedly divergent branching columns, generally without wall, with frequent overhanging laminae. Lamination is distinctly banded.

Content: *B. baicalica* (Maslov) Krylov, *B. kirgisica* Krylov, *B. rara* Semikhatov, *B. unca* Semikhatov, *B. prima* Semikhatov, *B. ampla* Semikhatov, *B. ingilensis* Nuzhnov, *B. maica* Nuzhnov, *B. aimica* Nuzhnov, *B. minuta* Komar, *B. capricornia* Walter and *B. burra* f. nov.

Age: Middle Riphean to early Late Riphean.

Baicalia burra f. nov.

FIGS. 4, 5, 6, 13, 14, 15a-c

Baicalia spp. Glaessner, Preiss & Walter 1969: 1056.

Material: Thirty-three specimens from ten localities.

Holotype: S222 (Figs. 13a & d), Skillogalee Dolomite 3.2 km west of Yatina, Southern Flinders Ranges.

Name: From the Burra Group in which the stromatolites occur.

Diagnosis: *Baicalia* with moderately frequent, slightly to markedly divergent branching, irregular, coalescing columns with highly variable lamina shape and continuous, distinctly banded microstructure.

Description

Mode of Occurrence: Two modes of occurrences have been noted: biostromal and biohermal, the latter occurring only at one locality

(Yatina). Biostromes vary in thickness from 0.3 to 2 m, the stromatolites being evenly distributed throughout their extent; they have been followed for 100 m or more, without lensing, before the outcrop disappears under soil cover. Biostromes are frequently interbedded in green shales (e.g. Myrtle Springs, Willouran Ranges), platy dolomites (e.g. Arkaroola, Worumba) or massive dolomites (e.g. Burra). The bioherms at Yatina are restricted to two thin beds; they are small lenticular stromatolitic mounds, approximately 20 to 30 cm thick and up to 1 m wide (Fig. 13a), interbedded with and surrounded laterally by platy and shaly dark grey dolomites. The overlying sediment is draped over the mounds, showing that the stromatolites had at least 10 cm relief over the surrounding surface. Columns arise from substrates in several ways: (1) Flat-laminated stromatolite passes gradually up into undulatory and pseudocolumnar stromatolites, then into discrete, vertical to inclined columns, often with steeply domed laminae (e.g. Burra, West Mount Hut); (2) Columns arise directly from eroded surfaces of laminated or intraclastic dolomites (e.g. Yatina, Fig. 4a)); (3) Columns arise from flat-laminated stromatolite *via* broad cumuli (e.g. West Mount Hut). The degrees of discreteness of columns varies greatly; in some beds, columns are almost immediately bridged over by laterally linked stromatolites, but usually columns remain discrete for 20 to 30 cm. In some areas new sets of columns may arise from pseudocolumns. The upper surfaces of biostromes vary from flat (e.g. in the Willouran Ranges, Burra) to broadly undulating (e.g. Worumba).

Column Shape and Arrangement: Columns are tuberous, varying from subcylindrical to irregular, with round, oval and irregular cross sections (Figs. 4, 5, 6). Elongated or flattened columns are variously oriented. The diameter of columns varies from 1 to 10 cm, most commonly 3-5 cm, with rapid swellings and constrictions. Columns are 2-15 cm high between branches. Some but not all columns are constricted at the point of branching (Figs. 4c, f; 5c, d). The orientation of columns varies greatly from vertical to inclined, and is sometimes sub-horizontal for short distances (Figs. 4c, 5j). Column axes vary from straight to strongly curved. In some specimens, the uppermost columns swell markedly upwards and become bridged over by laterally linked stromatolites. Adjoining columns coalesce very frequently, even in the discrete portions, but specimens from Burra show the least coalescing and bridging. In the Willouran Ranges, column growth is frequently interrupted by penecontemporaneous erosion; columns may grow over broken-off fragments of earlier columns, contributing to the irregularity of the structure.

Branching: The most common form of branching is moderately divergent (Fig. 4a, i, 6f) though some sub-parallel branching (Fig. 4e, g, m) and some very markedly divergent branching occurs (Figs. 4a, 5d & j). In some specimens several branches arise from nearly one point (Fig. 4a). Branching is moderately frequent, the length of column between branches commonly being only a few centimetres; but at any one point of branching it is usually dichotomous or less often trichotomous. In some specimens branches arise at a high angle to the main columns, and then turn sharply upwards. Some columns arise from the side of a main column (Fig. 14d). Great variation is seen even in single outcrops.

Margin Structure: The lateral surface varies from smooth to very irregular, laminae approaching the column margins at various angles. Some specimens have very patchy walls, while the intervening unwalled areas are smooth or only slightly fringed with small peaks and cornices, for example those from Burra (Fig. 14d), Yatina (Fig. 4a), River Broughton (Fig. 5c), Arkaroola (Fig. 5d, e). Willouran Ranges specimens contain both smooth and highly irregular edges, with large overhanging peaks composed of one or more laminae (Fig. 6b & c). Frequently large swellings are composed of numerous laminae overhanging a constricted portion of a column (Fig. 4c). Bridges between columns are especially common near the tops and bottoms of biostromes (Fig. 6e).

Lamina Shape: The lamina shape is most commonly gently convex, but varies in single specimens from very gently convex to nearly conical; many laminae are steeply convex. Microunconformities are especially prominent in specimens from the Willouran Ranges, but occur to some extent in all areas. In places, branching commences upon a partly eroded column surface (Fig. 15b). Fig. 8d illustrates the more commonly occurring lamina shapes; 92% of lamina have h/d between 0.1 and 0.6, the mode being h/d between 0.3 and 0.4 (28%) (Fig. 9d). Generally, the widest columns have the most gently convex laminae, while strongly elongated columns have laminae gently convex in the section parallel to the long

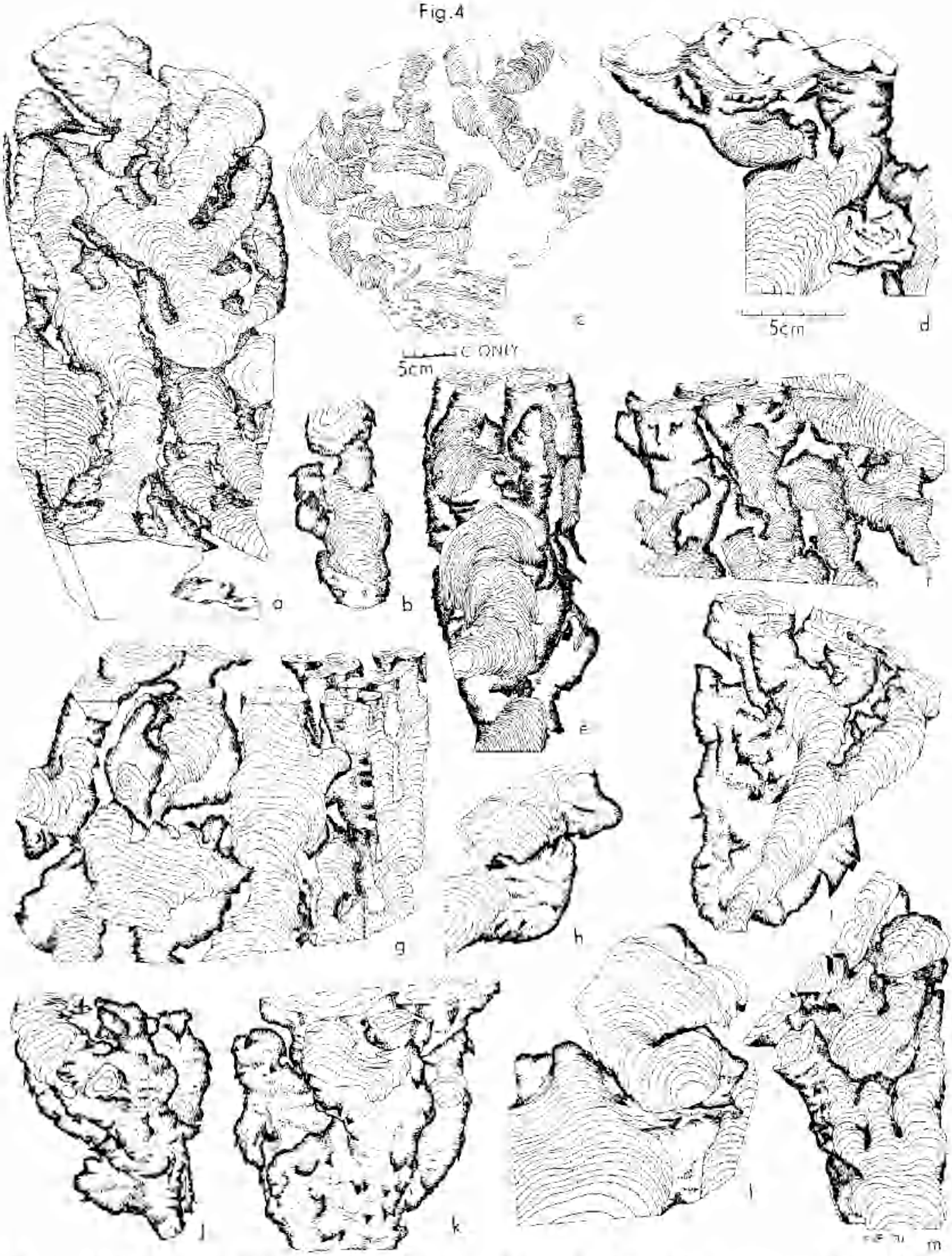

Fig. 4. *Baicalia burra*. Skillogalee Dolomite, Burra Group, Southern Flinders Ranges: (a) & (c)—Holotype. S222, 3.2 km W. of Yatina; (b)—S218, same locality; (d) S151, 13 km S.W. of Worumba H.S.; (e) & (f)—S151, same locality; (g), (i) & (j)—S221, Dutton's Trough H.S., 14 km S. of Burra; (h) & (l)—S314, same locality; (k)—S534, same locality; (m)—float specimen, River Broughton, W. of Spalding.

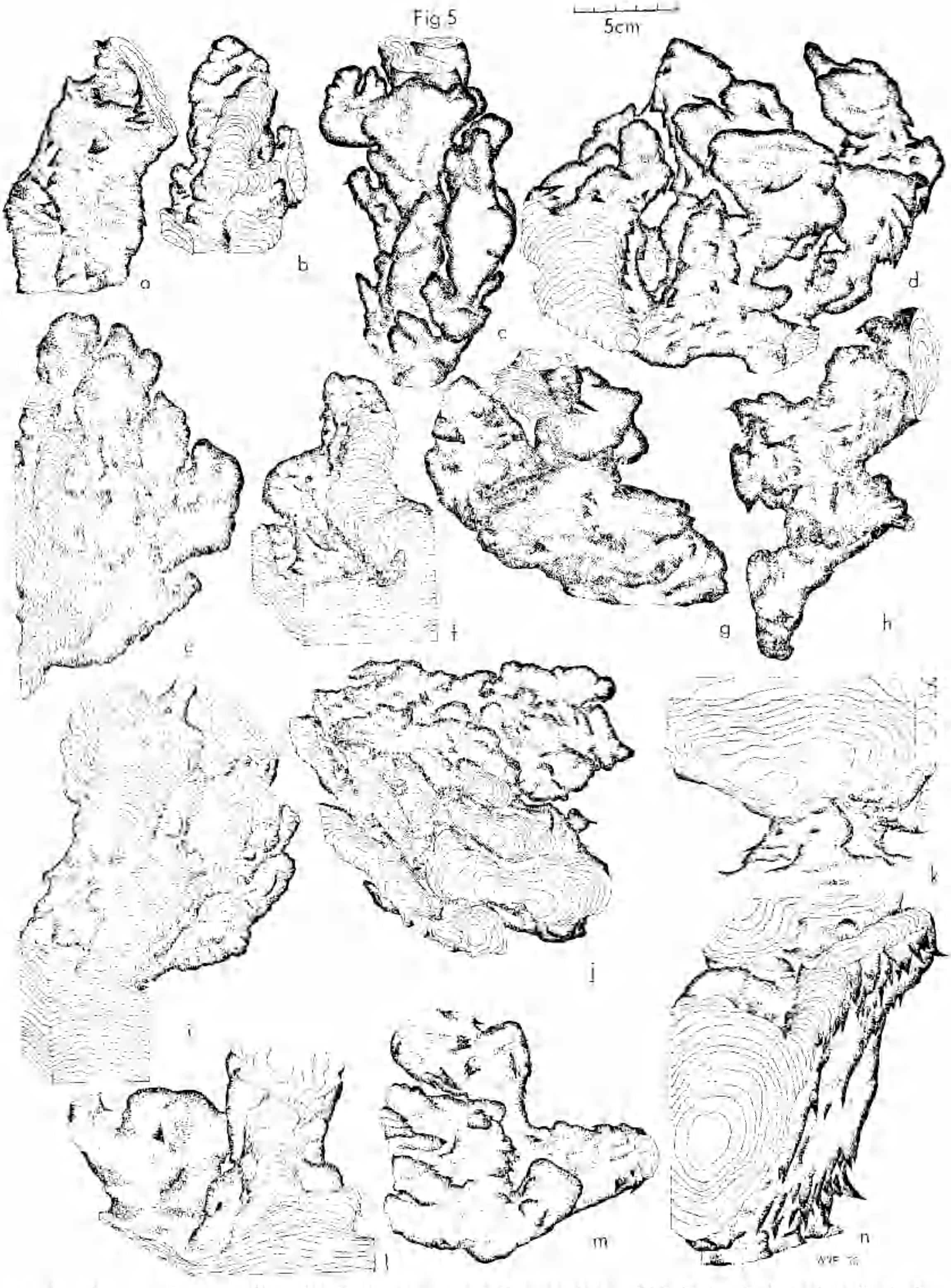

Fig. 5. *Baicalia burra*, Skillogalee Dolomite, Burra Group: (a)—S533, Dutton's Trough H.S., 14 km S. of Burra; (b)—S534, same locality; (c)—S383, River Broughton, W. of Spalding; (d)—S456, 6.4 km S. of Arkaroola; (e)—S457, same locality; (f)—S491, 2.4 km E. of Myrtle Springs H.S. (upper member of Skillogalee Dolomite); (g)—S489, same locality; (h)—S490, same locality; (i)—S488, 1.6 km E. of Myrtle Springs H.S. (lower member of Skillogalee Dolomite); (j)—S487, same locality; (k)—S319, the Avondale Mine, Lyndhurst (collected by Mr. P. J. Binks); (l)—S302, West Mount Hut, Willouran Ranges; (m)—S99, same locality (collected by Mr. C. R. Dalgarno); (n)—S97, near Chintapanna Well, Willouran Ranges (collected by Mr. C. R. Dalgarno).

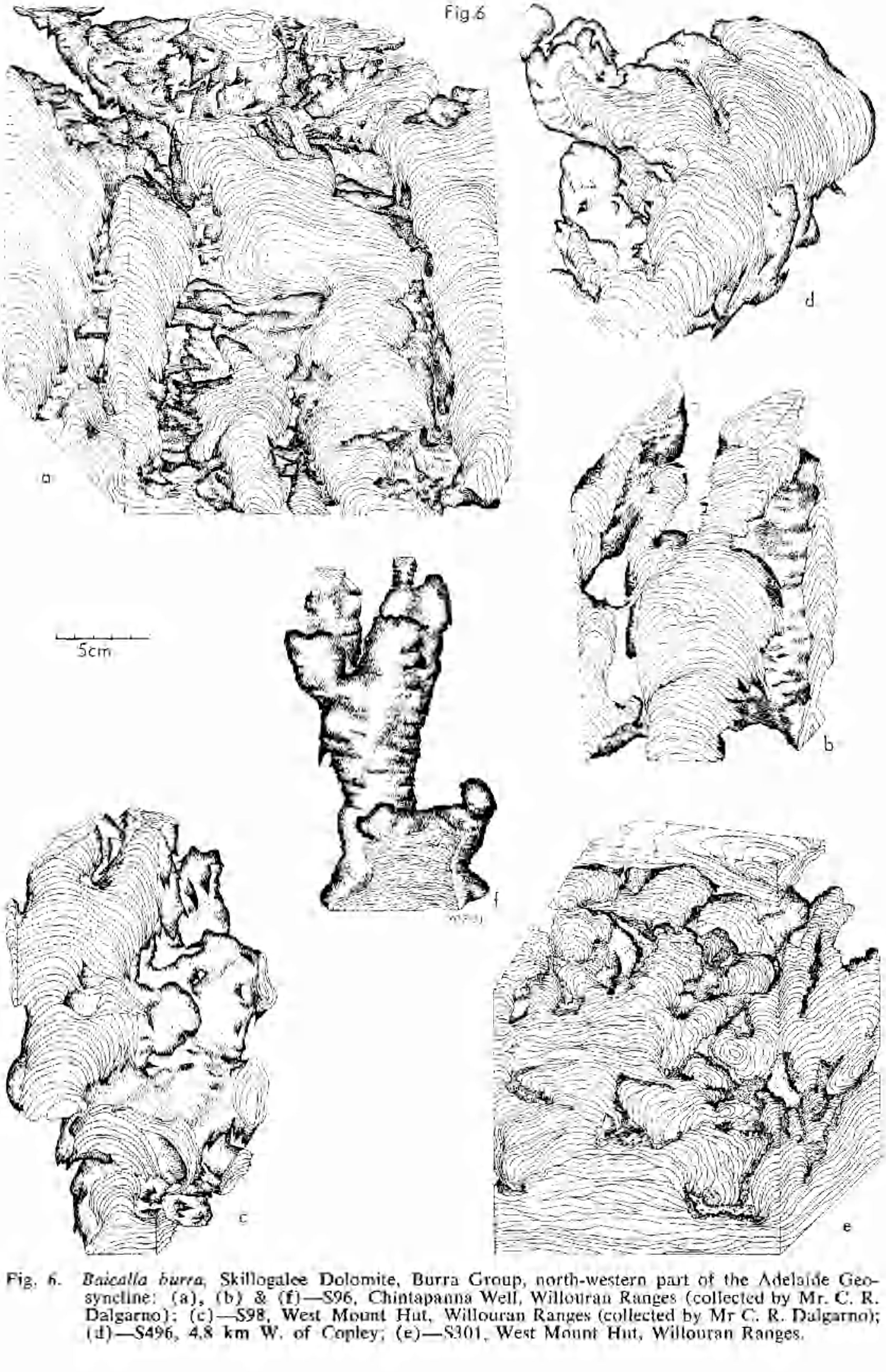

Fig. 6. *Baicalia burra*, Skillogalee Dolomite, Burra Group, north-western part of the Adelaide Geosyncline: (a), (b) & (f)—S96, Chintapanna Well, Willouran Ranges (collected by Mr. C. R. Dalgarno); (c)—S98, West Mount Hut, Willouran Ranges (collected by Mr C. R. Dalgarno); (d)—S496, 4.8 km W. of Copley; (e)—S301, West Mount Hut, Willouran Ranges.

axis, and steeply convex at right angles to it. Rarely do laminae turn over sharply and thin at the column margins, to form a wall. Generally, where a patchy wall is present, it is formed by the edges of steeply convex or parabolic laminae (Fig. 14c). Frequently, laminae develop two crests, anticipating branching immediately above (Fig. 4a, m). On a smaller scale, lamina shape varies from smooth and regularly curved to slightly wavy, with discontinuous curvature and sharp crests. Both types occur in single specimens (Fig. 14).

Microstructure: The microstructures and textures observed in the different areas vary considerably depending on the degree of recrystallization. In the best preserved specimens, the layering comprises alternating relatively thick, continuous, very distinct, light and dark laminae, giving a banded appearance. Some are single homogeneous thick layers, while others are macrolaminae consisting of several very thin light-dark lamination pairs. Most commonly single laminae traverse the whole column width, except where cut by micro-unconformities. Ooids or other detrital grains may be included in the laminae. Upper and lower boundaries of laminae are usually smooth and even, sometimes wavy or broadly wrinkled, but always more or less parallel. Exceptions occur only where erosional scour has taken place during growth. Rarely, lenticular swellings occur. *Light laminae* vary in thickness from 0.02 to 0.5 mm, very rarely to 1.0 mm. Most light laminae thin towards the column edges, but rarely lens out. In the best preserved specimens, the sparry dolomite forming them is inequigranular, xenotopic, and of grain size ranging from 0.005 to 0.06 mm. With greater recrystallization an equigranular mosaic of 0.05 to 0.2 mm grain size results (e.g. Burra). The light laminae usually have sharp and smooth upper boundaries, but sometimes grade down into grumous textured laminae, consisting of irregular and interconnected micritic patches up to 0.1 mm diam., set in xenotopic equidimensional sparry dolomite with a grain size of about 0.01 to 0.03 mm, i.e. partially recrystallized dark laminae. In some specimens (e.g. Yatina, West Mount Hut, Worumba), the light laminae contain detrital granules, including small flat intraclasts, up to 0.5 mm long, and rare ooids up to 0.3 mm in diameter. Overlying laminae are draped over the larger detrital grains. Laminae in the Copley specimen may be pelletal (Fig. 14e). *Dark laminae* occur either singly, alternating with light laminae, or in dark macrolaminae. Thin dark laminae are commonly 0.04 to 0.3 mm thick, but macrolaminae range up to 2.5 mm in thickness, generally constant across the column, or thinning slightly towards the margins. They are either continuous, or consist of a series of aligned lenses, each up to 0.2 mm long. In well preserved specimens the dark laminae have smooth, sharp, parallel boundaries; rarely, single laminae may be wrinkled, suggesting intraformational crumpling during growth. Well preserved dark laminae consist of dense, brownish-pigmented xenotopic dolomite, of equidimensional grains 0.003 to 0.01 mm diam., but vertical and lateral gradations from unaltered to grumous textures are common. Where dark laminae are grouped into macrolaminae, they alternate with very thin, discontinuous light laminae, and frequently fuse to form solid, thick dark laminae.

Interspaces: A few specimens have interspaces filled predominantly with bedded dolomite mud (e.g. Burra), but generally the sediment is unbedded intrasparite or oosparite, less commonly intramicrite. Frequently, intraclasts are derived from the erosion of stromatolitic columns; in places, a large fragment torn from a column has acted as a base for new growth. Intraclasts are flat to gently curved tabular dolomite pebbles up to 3 cm long, 1 to 2 mm thick, and only slightly rounded. Many are fragile and could have survived very little transport. They contain the typical internal laminations of the associated stromatolites, and are probably derived directly from them. Occasional flat pebbles stand vertically, but generally they lie flat or imbricated. Ooids vary in shape from round to oval, 0.2–1.0 mm diam., and consist of one dark-rimmed sparry layer coating a micritic core, or less commonly, several sparry layers. Most commonly, allochems are closely packed and cemened by a clear, sparry dolomite cement. Some specimens contain significant amounts of dolomite mud, variously recrystallized, forming a matrix between allochems; in these cases the sediment is poorly laminated.

Secondary Alteration: Secondary alteration has extensively modified the textures and often the microstructures of stromatolites from many areas. The following four stages of alteration may be recognized:

(1) *Penecontemporaneous.* The fact that dolomite consistently constitutes the whole rock to the exclusion of calcite, while still preserving fine structures, suggests very early dolomitiza-

tion, during the growth of the stromatolites. It is also possible that penecontemporaneously dolomitized lime muds were reworked and trapped in the algal mats. During growth, erosion by strong currents scoured the living surfaces of columns, creating micro-unconformities. In some specimens (e.g. West Mount Hut), laminae may be separated by lenticular vughs, later filled with sparry dolomite (Fig. 12c). These voids were probably formed by arching up of laminae, perhaps due to lateral expansion in growth of the algal mats building the stromatolites, or to partial desiccation.

(2) *Early Diagenetic*. Black chert very commonly replaces portions of stromatolites and interspace sediments. Sometimes dark laminae are preferentially silicified, perhaps during growth, but more commonly, silicification postdates the growth of the columns (e.g. one side of a column may be replaced). In places, silicified laminae are broken by minute dolomite filled cracks.

(3) *Late Diagenetic*. Dark laminae and macrolaminae may be recrystallized to grumous textures, consisting of patches of dark, dense micritic dolomite (remnants of the original carbonate) varying greatly in size from 0.005 to 0.1 mm, set in a matrix of xenotopic sparry dolomite, of equidimensional grains ranging in size from 0.01 to 0.03 mm. Light laminae are commonly slightly recrystallized and sparry, consisting of hypidiotopic to idiotopic equidimensional dolomite grains of similar size to those of the sparry matrix of the grumous textures. Coarsely recrystallized laminae also occur, in places cutting across the fine structure of primary laminae and corroding their boundaries. They consist of idiotopic transparent dolomite of grain size up to 0.1 mm.

(4) *Tectonic*. The only specimens affected by tectonic deformation are from the Burra region. Here columns are slightly flattened and laminae are crenulated along a slight tectonic foliation. These are also the most highly metamorphosed, displaying the greatest degree of recrystallization. Tensional joints filled with coarsely crystalline dolomite are common in most areas.

Comparisons

The stromatolites are assigned to the group *Baicalia* on the basis of their tuberous, swelling and constricting, bumpy, variously oriented columns, general absence of wall, numerous overhanging peaks and short cornices, and generally divergent branching. Some specimens have horizontal columns for short distances resembling *Tungussia*, but are distinguished by the absence of the multiple horizontal branching characteristic of *Tungussia*, and by their generally more ragged column margins. *Baicalia burra* is distinguished from *B. prima* Semikhatov, *B. aimica* Nuzhnov, and *B. capricornia* Walter, by its frequently divergent branching and general complexity of columns, and from *B. minuta* Komar by its larger size and more complex structure. Some specimens resemble *B. baicalia* (Maslov) Krylov, but most have more inclined and irregular columns. *B. lacera*, *B. rara*, *B. ampla* and *B. unca* Semikhatov are not adequately illustrated for reliable comparison, and the illustrated microstructures are badly altered; single specimens of *B. burra* may show microstructures similar to *B. unca*, *B. lacera*, and especially the pelletal laminae of *B. rara*. Some specimens have long overhanging peaks and thus resemble *B. ingilensis* Nuzhnov, but are distinguished by more frequent and divergent branching. *B. burra* most closely resembles *B. rara* Semikhatov and *B. maica* Nuzhnov; it is distinguished from *B. rara* in that neither pelletal laminae nor knee-shaped bends in columns are consistently developed, and from *B. maica* by its more irregular and coalescing columns, and its more continuous laminae.

Distribution: Widespread in the Skillogalee Dolomite, Burra Group: Dutton's Trough H.S., 16 km south of Burra; Scrubby Range, 27 km south of Burra; 3 km west of Yatina; River Broughton, 8 km west of Spalding; 11 km south-west of Worumba; 11 km south of Arkaroola; 3 km west of Copley; 3 km east of Myrtle Springs H.S. near Leigh Creek; West Mount Hut, 27 km west of Witchelina H.S. and Chintapanna Well, about 16 km west of Witchelina H.S. Possible *B. burra* occurs also in the Skillogalee Dolomite, Depot Creek, but these have not been studied in detail. Specimens from possible River Wakefield Group, Carrieton (Fig. 15e) are inadequate for identification, but are possibly to be included (BURRA, ORROROO, PARACHILNA, COPLEY, ANDAMOOKA and CURDIMURKA 1:250,000 map sheet areas).

Age: Early Adelaidean, correlated with the youngest Middle Riphean of the USSR.

Group BOXONIA Korolyuk

Boxonia Korolyuk 1960:139. Komar 1966: 79. Cloud & Semikhatov 1969:1036. Glaessner, Preiss & Walter 1969:1056.

Type Form: *Boxonia gracilis* Korolyuk, from the Bokson Suite, Eastern Sayan.

Diagnosis: Straight, subcylindrical columns with moderately frequent α- to β-parallel branching and smooth, walled margin structure.

Content: *B. gracilis* Korolyuk, *B. lissa* Komar, *B. kraslvica* Golovanov, *B. allahjunica* Komar & Semikhatov, *B. ingilica* Komar & Semikhatov, *B. bianca* Raaben and *B. pertaknurra* Walter. Raaben (1969a) places *B. grumulosa* Komar into partial synonymy with *B. gracilis* Korolyuk. *B. diverata* Sidorov has only a patchy wall and may therefore be excluded.

The South Australian form is *Boxonia melrosa*.

Age: Late Riphean and Vendian.

Boxonia melrosa f. nov.

FIGS. 7a–h, 15d–f

Material: Four specimens from one locality.

Holotype: S503 (Figs. 7b, c & d; 15e), 1.6 km west of Melrose township, Southern Flinders Ranges.

Name: After the type locality.

Diagnosis: *Boxonia* with long, narrow, closely spaced columns, α- and β-parallel branching, without very broad basal columns, with occasional rounded projections, and with indistinctly banded, moderately convex, laminae lacking pelletal microstructure.

Description

Mode of Occurrence: The stromatolites are relatively poorly exposed in a faulted area, so that relationships are not clear. At least two bioherms occur, preserved as grey or pale buff dolomite. The beds are overturned, dipping south at about 40°. The narrow, parallel columns arise directly from laterally linked stromatolites, partly pseudocolumnar, the base of which is not exposed. The overlying columnar portion is approximately 6 m thick and consists of vertical columns near the centre of the bioherm, and inclined columns at the margins, where they pass laterally into pseudocolumnar stromatolites. Columns are overlain by wavy laminated stromatolites, which cover the whole bioherm. Bioherms are of cumulate shape, broadly domed, up to 60 m long, and are surrounded by flat-bedded dolomite.

Column Shape and Arrangement: Columns are straight, erect, subcylindrical, smooth to gently bumpy, with circular or slightly lobate, rounded polygonal cross-sections, 1–5 cm diam. (Fig. 7a–h). The diameter of a single column generally remains constant throughout its length. Columns may reach a length of up to 20 cm between branches, but some columns are only a few centimetres high, occasionally in the form of rounded projections.

Branching: Branching varies from α- to β-parallel; γ-parallel branching is rare (Fig. 7h). Commonly a 3–5 cm column divides into two or three narrower, parallel, very closely spaced columns, 1–2 cm diam. (Fig. 7c,d,f). Occasionally, two narrow columns may coalesce (Fig. 7c). Not all branches develop into long columns; some terminate their growth only a few centimetres above branching (Fig. 7d).

Margin Structure: The lateral surface is even, smooth or with low, broad bumps, up to several centimetres wide, with a relief of 1–5 mm. Peaks and cornices are entirely absent, but very rarely bridges up to 1 cm thick occur between adjacent columns. A multi-laminate wall is almost ubiquitous. At the margins of columns laminae are poorly preserved, but in places up to 10 laminae may be seen to comprise the wall. Single laminae generally extend for a distance of 1–2 cm down the column margin (Figs. 15d–f).

Lamina Shape: Laminae are most commonly moderately convex, hemispherical, in places approaching rectangular (Fig. 8e). Frequently they are slightly asymmetrical, especially in inclined columns. Before branching, laminae usually develop two crests. The degree of convexity, h/d, is moderately constant, even in columns of differing widths. Of laminae measured, 91% have h/d between 0.3 and 0.7, the mode (39%) being 0.5–0.6 (Fig. 9e). The shape of crests varies from tightly arcuate to gently rounded (Fig. 8e). Most laminae are broadly wavy (wavelength up to 8 mm, amplitude 1–2 mm) but not wrinkled.

Microstructure: Microstructure is poorly preserved in both pale and dark specimens; laminae are broadly continuous, with smooth, parallel upper and lower boundaries, but may be broken into a series of clots and lenses by recrystallization, and even where their continuity is preserved, they are extensively embayed by recrystallized carbonate. Microstructure is indistinctly banded with alernating darker and lighter laminae. *Light laminae* vary in thickness from 0.08–0.4 mm, but usually thin towards column margins. Continuity is usually retained across a column, although the finest laminae frequently lose their identity by recrystallization. The laminae consist of transparent, slightly inequigranular (of grain size 0.01–0.04 mm) equidimensional dolomite of polygonal, hypidotopic texture. Within this occur irregular 0.05–0.1 mm segregations of darker, greyish pigment, with no relation to grain boundaries. These are apparently remnants of pigment left by partial recrystallization, as they may grade into more or less continuous laminae. Distinct round to oval pellets (as in Russian *Boxonia*) are absent. *Dark laminae* are less continuous, and often diffuse. Their thickness varies from 0.08–0.3 mm; towards the margins they frequently thin or lens out completely, and do not take part in the formation of the wall. (The layering in the wall is

Fig.7

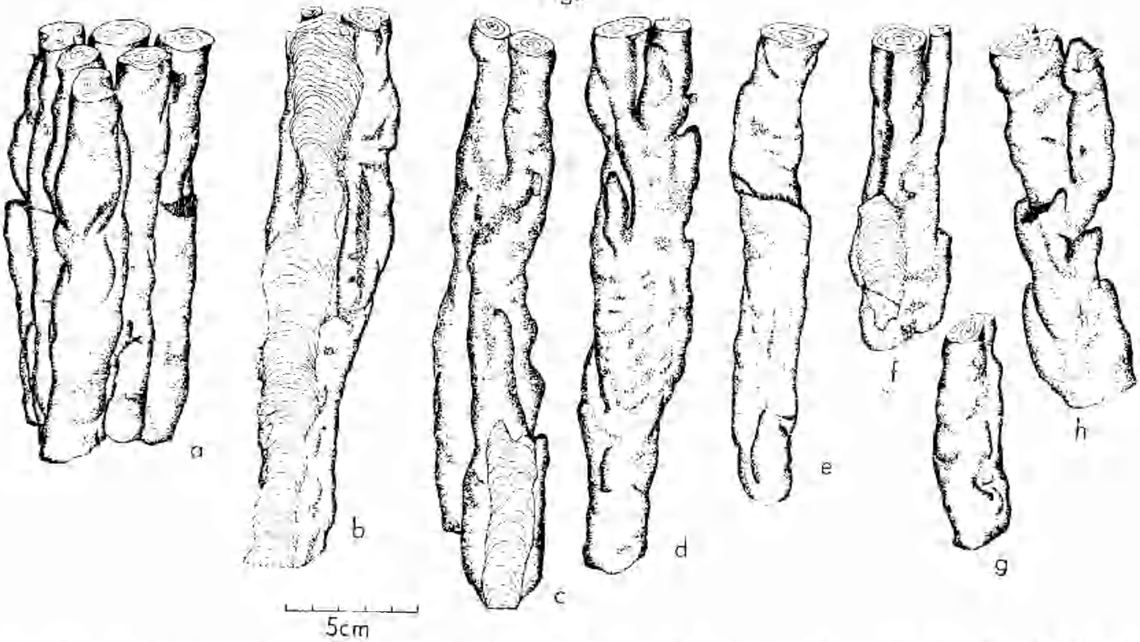

Fig. 7. *Boxonia melrosa*, Brighton Limestone equivalent, Umberatana Group, 1.6 km W. of Melrose: (a), (e), (g) & (h)—S502; (b), (c) & (d)—Holotype, S503; (f)—S504.

Fig.8

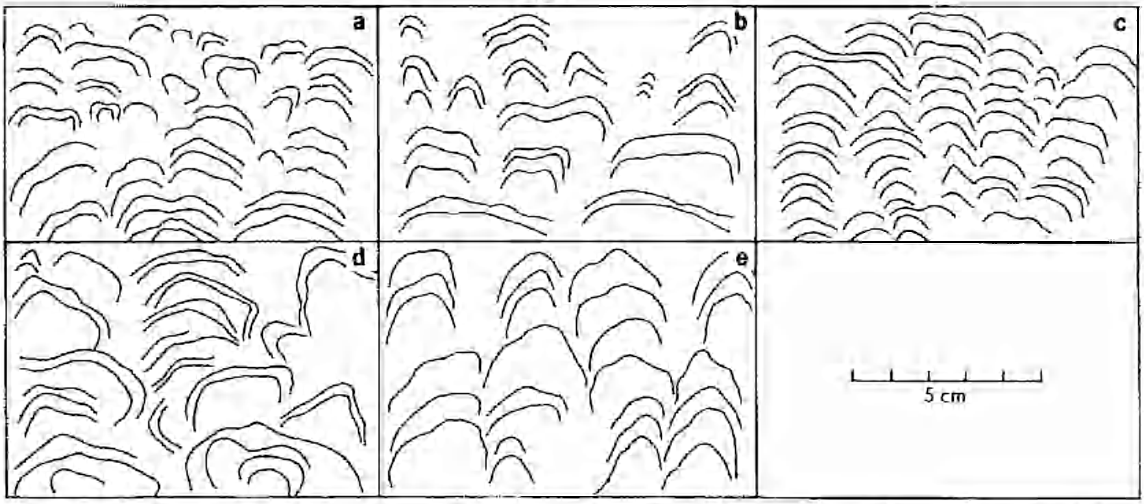

Fig. 8. Representative examples of lamina shape: (a)—*Acaciella angepena*; (b)—*A. augusta*; (c)—*Acaciella* f. indet.; (d)—*Baicalia burra*; (e)—*Boxonia melrosa*.

extremely indistinct). In places, they lens out also within the central part of a column. Dark laminae are composed of equidimensional, xenotopic, equigranular dolomite (of grain size ranging from 0.003–0.01 mm), and in places, are disrupted into a series of irregular clots and lenses separated by sparry dolomite.

Interspaces: Interspaces between columns are extremely narrow (usually less than 5 mm), and are filled with partially recrystallized dolomite mud, now largely of finely grumous texture, containing in places, round or ovoid clastic pellets, 0.2–0.7 mm diam. Much of the sediment is vaguely laminated, the laminae abutting against the walls of columns, which they postdate.

Secondary Alteration: Stromatolite columns and interspaces consist of dolomite, considered to result from the replacement of original calcium carbonate. Most fine structure has been lost; dark laminae are outlined mainly by segregations of dark pigmented dolomite, but recrystallization has partly embayed and partly obliterated the fine dark laminae. The irregular distribution of pigment is due to recrystallization. In places, coarser, sparry laminae of grain size up to 0.08 mm occur, and may contain dismembered remnants of dark laminae. Stylolites are moderately frequent, and usually discordant to the lamination. In places they follow column margins for short distances, removing the wall. Occasional thin dolomite veins follow the path of stylolites. Some stylolites are parallel to overall bedding, and displace column axes slightly (Fig. 7c).

Comparisons

The stromatolites are assigned to the group *Boxonia* on the basis of their long, smooth walled columns with moderately frequent α- and β-parallel branching. *Katavia* Krylov and *Acaciella* Walter have similar gross structure; *Katavia* is distinguished by its very prominent bumps, while *Acaciella* generally lacks a wall. *Minjaria* Krylov also has parallel straight columns but is distinguished by its less frequent branching. Most other described forms of *Boxonia* have well defined pelletal microstructures; forms are largely distinguished on the basis of the size of the pellets. A specimen of *B. gracilis* sent by M. A. Semikhatov and I. N. Krylov, has pellets consisting of rounded carbonate grains with dark, fine-grained rims. These are absent in *B. melrosa*, which also has less wrinkled laminae. *B. melrosa* is distinguished from *B. ingilica* Komar & Semikhatov by its ubiquitous wall and straight columns; *B. allahjunica* Komar & Semikhatov apparently has some complex branching. *B. lissa* Komar, *B. gracilis* Korolyuk, *B. grumulosa* Komar, *B. bianca* Raaben and *B. krasivica* Golovanov

Fig.9

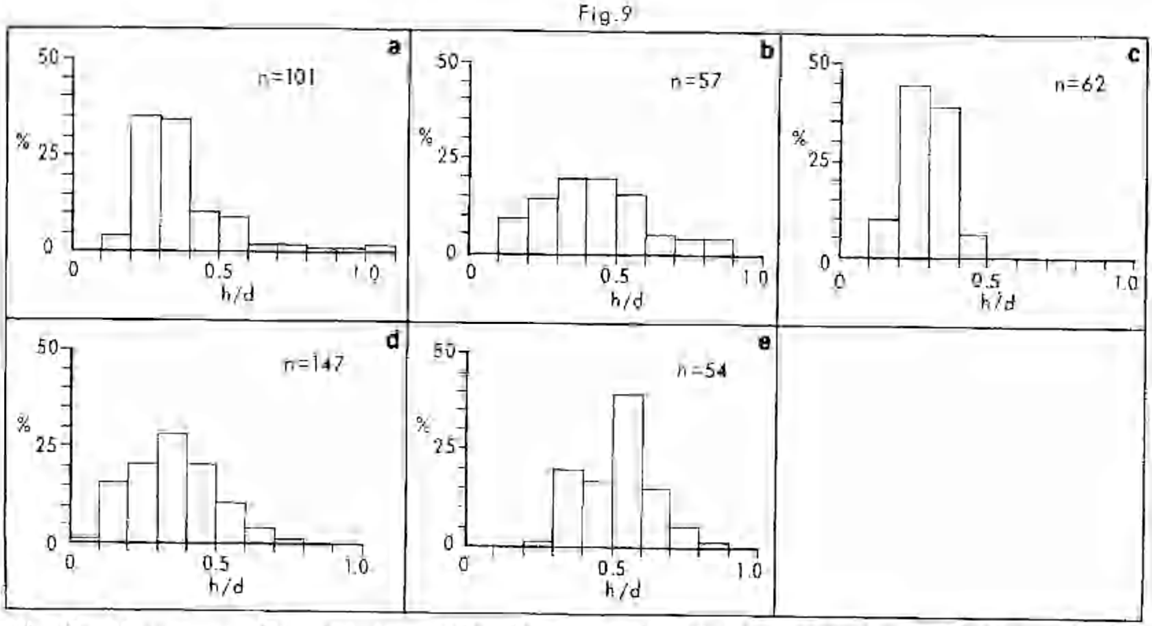

Fig. 9. Histograms of lamina convexities. The convexity of a lamina is the ratio of the height of that lamina to its diameter (h/d). Histograms are plotted for each stromatolite form at intervals of 0.1; *n* is the number of measurements made for each form: (a)—*Acaciella angepena*; (b)—*A. augusta*; (c)—*Acaciella* f. indet.; (d)—*Baicalia burra*; (e)—*Boxonia melrosa*.

may all be synonymous. *B. melrosa* is distinguished from *B. pertaknurra* Walter (in press), which also lacks a pelletal microstructure, by its more steeply convex laminae, its occasional short, projection-like columns and by the absence of well defined broad basal columns. *B. melrosa* most resembles *B. lissa,* from which it is distinguished by the absence of pelletal microstructure, and by the presence of some short, projection-like columns.

Distribution: Brighton Limestone equivalent, 1.6 km west of Melrose (ORROROO 1:250,000 map sheet area).

Age: Late Adelaidean, correlated with the Late Riphean of the USSR.

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Appendix 1.—Glossary

Axis: The centre-line of a column.

Bioherm: A circumscribed organo-sedimentary structure whose minimum width is less than or equal to one hundred times its maximum thickness, embedded in rocks of different lithology. Note: the definitions of the terms *Bioherm* and *Biostrome* are based on those given by Nelson, Brown & Brineman (1962) but since, at least in stromatolites, the two integrade, an arbitary limit must be set.

Tabular bioherms have parallel upper and lower surfaces, while *domed bioherms* have gently convex upper surfaces. *Subspherical bioherms* had the highest growth relief relative to their width.

Tonguing bioherms are bioherms which had little or no growth relief, and therefore intertongue at their margins with the surrounding sediment.

Biostrome: A stratiform organo-sedimentary structure whose minimum width is more than one hundred times its thickness. Note: in practice it is rarely possible to see the three dimensional shape of the structure in outcrop. The distinction between bioherms and biostromes must therefore be based on the dimensions visible in outcrop. If the outcrop is inadequate, the informal term "bed" is used.

Tabular biostromes have parallel lower and upper surfaces. *Domed biostromes* either may consist of juxtaposed domed bioherms or may be continuous with juxtaposed domes on their upper surfaces.

Branching: The division of a column into new, discrete columns. The columns become discrete when they are first separated by an interspace. In *parallel* branching, the *axes* of the new columns are parallel (most commonly they are also parallel to the axis of the original column). *α-parallel branching* is parallel branching in which the width of the individual remains constant. In *β-parallel branching* the original column widens gradually before branching, while in *γ-parallel branching*, it widens abruptly before branching. In *slightly divergent branching*, the axes of the new columns diverge at less than 45°, while in *markedly divergent branching* they diverge at more than 45°. *Dichotomous branching* is branching into more than two columns at approximately one level.

Bridge: A stromatolitic lamina or set of laminae linking adjacent columns.

Bump: A low, rounded protrusion on the side of a column.

Coalescing columns: Adjacent columns which join and continue growth as one column.

Column: A discrete stromatolite structure, with the dimension in the direction of growth greater than at least one of the transverse dimensions. Column shape and arrangement often vary according to the position in the bioherm.

Columnar-layered stromatolite: A stromatolite in which short columnar and laterally linked (usually pseudocolumnar) portions alternate.

Cornice: Peripheral overhanging portion of a lamina or set of laminae, elongated transversely to the column axis.

Crest: The summit of an upward-convex lamina.

Crestal line: The line jointing the crests of successive laminae.

Crestal zone: The environs of the crestal line. In *Conophyton*, the crestal zone is specifically the zone of thickening and contortion of the laminae; the width of the crestal zone is the width of the thickened and/or contorted portions of laminae. Three types of crestal zones of *Conophyton* were distinguished by Komar *et al.* (1965).

Cumulate stromatolite: A rounded protruding non-columnar stromatolite.

Domed: With approximately constant radius of curvature.

Flat-laminated stromatolite: Non-columnar stromatolite with flat continuous laminae. Aitken (1967) has proposed the term *cryptalgalaminate* for stromatolites with planar lamination.

Gently convex lamina: A lamina whose ratio of height to diameter is less than or equal to 0.5. Measurements of this ratio are best treated statistically by plotting on a histogram.

Gnarled column: A column with large bumps.

Grumous: A mineral texture in which fine-grained patches are surrounded by coarser grains, interpreted to have formed by partial recrystallization.

Hypidiotopic: A mineral texture intermediate between xenotopic and idiotopic.

Idiotopic: A texture in which the mineral grains are bounded by crystal faces.

Individual: A single discrete stromatolite within which either the laminae are continuous or which comprises a group of columns arising from a single basal column.

Interspace: The space between columns, usually filled with sediment.

Lamina: The smallest unit of layering in a stromatolite.

Lanceolate: An elongate transverse section of a column, tapering at both ends.

Laterally linked stromatolite: Stromatolite with wavy laminae which are continuous between crests.

Macrolamina: A distinct set of laminae.

Microstructure: The fine-scale structure of the stromatolite lamination, in particular the distinctness, continuity, thickness and composition of the laminae.

Banded microstructure is characterized by very continuous laminae with sharp, distinct, more or less parallel boundaries. In *streaky microstructure* less distinct and continuous laminae frequently grade into one another. The darker laminae are usually more distinct.

Striated microstructure consists of primary chains of lenses, oriented parallel to the lamination (this excludes cases where originally continuous laminae are disrupted by recrystallization).

Vermiform microstructure consists of narrow, sinuous, pale coloured areas (usually of sparry carbonate) surrounded by darker, usually finer grained areas.

Micro-unconformity: Surface of lamination discordance due to penecontemporaneous erosion within a stromatolite.

Niche: A deep indentation in the side of a column.

Parabolic lamina: A lamina whose axial longitudinal section approximates a parabola.

Peak: Overhanging portion of a lamina or set of laminae with a small dimension transverse to the column.

Pellet: Ovoid to sub-ovoid micritic carbonate grain of silt or sand size, lacking internal structure.

Pigment: Organic or inorganic colouring matter.

Platy column: A strongly transversely elongated column.

Projection: A small columnar or conical outgrowth from the side of a column.

Pseudocolumnar stromatolite: Laterally linked stromatolite in which successive crests are superimposed, forming column-like structures (pseudocolumns).

Rectangular lamina: Lamina which in a longitudinal section of a column is flat-topped with edges deflexed at about 90°.

Rhombic lamina: Lamina which in a longitudinal section of a column is flat-topped but has subparallel edges not perpendicular to the top.

Rib: A low, rounded protrusion which is elongated transversely to the column on which it occurs.

Selvage: An unlaminated coating on column margins. Possible explanations for this include (a) micritization by algal boring; (b) inorganic precipitation of lime; (c) a thin algal film on column margins during growth. In some forms a selvage-like structure is probably the result of differential recrystallization of a wall.

Steeply Convex lamina: A lamina whose ratio of height to diameter is greater than 0.5.

Tuberous column: A column with prominent expansions and constrictions.

Wall: Structure at the margin of a column formed by one or more laminae from within the column bending down and coating the margin for at least a short distance.

Wavy lamina: A lamina with flexures of wavelength greater than 2 mm.

Wrinkled lamina: A lamina with flexures of wavelength greater than 2 mm.

Undulatory stromatolite: Laterally linked stromatolite in which successive crests are not superimposed.

Xenotopic texture: A texture in which the mineral grains are anhedral or irregularly shaped, i.e. not bounded by crystal faces.

Fig. 10. *Acaciella angepena*, from Lower Cambrian limestones, Flinders Ranges; sections perpendicular to bedding, showing mode of occurrence and microstructures: (a)—Marginal section of a bioherm. Note that the laminae are completely recurved under the bioherm edge. The specimen is *in situ*. The ball-point pen is 16 cm long, Angepena; (b)—Etched section of S300, the recurved margin of the bioherm in (a) cut at right angles to bedding. Note that here growth partly proceeded downwards. Specimen is 15 cm wide; it was collected from the outcrop shown in (a); (c)—Lateral termination of a bioherm, which partly sank into the soft substrate during growth. The white areas are dolomitized. Width of specimen (S460) is 20 cm. Angepena; (d)—Pseudocolumns with rare interspaces. Note the domed laminae grown upon partly buried intraclasts, and the extremely continuous lamination. Thin section. Angepena (S462); (e)—Evenly laminated ferruginous structure, probably the stromatolite *A. angepena* affected by secondary ferruginization. Thin section, from near Old Wirrealpa. The dark laminae are outlined by finely disseminated hematite. (S564, collected by Mr. P. G. Haslett); (f)—Evenly laminated discrete columnar form from Italowie Gorge (Sir Douglas Mawson's specimen).

Fig. 11. (a)—*Acaciella angepena*; irregular columns from the marginal portion of a small bioherm (S458, Angepena). Note the vermiform microstructure within parts of columns, here interpreted as due to algal boring, disrupting the normally very even, continuous lamination; (b) & (c)—*Acaciella* f. indet. Both specimens are erratics from the Sturtian glacials north of the Enorama Diapir. Thin sections. Note the very numerous concordant stylolites in (b). (S539 and S509 respectively; S539 was collected by Dr. B. Daily); (d), (e) & (f)—*Acaciella augusta*, Brighton Limestone equivalent, Depot Creek. Vertical sections showing mode of occurrence and microstructure; (d)—Details of transition from broad, frequently bridged basal columns to upper narrow, discrete columns. Broad columns in lower right-hand corner have inclined margins and subhorizontal laminae; (e)—Lenticular open spaces between laminae, possibly representing original gas vesicles (S163); (f)—Portion of a bioherm showing the intercalation of columnar and laterally linked stromatolites.

Fig. 12 *Acaciella augusta*, Brighton Limestone equivalent, Depot Creek, showing mode of occurrence and microstructures. (a)—Margin of a bioherm (pale coloured at right of photograph) intertonguing laterally with massive oosparite (at left); (b) & (c)—S404 & S401 respectively. The gross shape and branching of columns. The interspaces are filled with interlayered micrite and intramicrite, in 0.5 to 1.0 cm bands. (c) is natural size. In (b), laminae become doubly crested before branching, but in the centre of the photograph (c) is an example of a short interspace between crests bridged by the overlying laminae; the column then resumes its former growth pattern; (d)—Recrystallized specimen from Mundallio Creek (S538), illustrating radiating recrystallized acicular textures in the lower part of the photograph.

Fig. 13. *Baicalia burra*, Skillogalee Dolomite. Sections perpendicular to bedding, showing the mode of occurrence and microstructure: (a)—Small lenticular bioherms interbedded in thinly bedded dolomites, Yatina; (b)—Portion of a biostrome interbedded in massive, fine grained dolomites, Dutton's Trough H.S. Longitudinal section of partially silicified columns. The section is parallel to the tectonic cleavage, in the plane of flattening of the columns; (c)—Irregular columns with numerous micro-unconformities and highly variable lamina shape, West Mount Hut; (d)—Moderately divergent branching columns, with some pelletal laminae. Thin section, Yatina (S222, holotype); (e)—Slightly divergent branching in regular, sub-cylindrical columns. Thin section, S533, Dutton's Trough H.S.; the specimen is taken from the biostrome shown in Fig. 13 (b).

Fig. 14. *Baicalia burra*, Skillogalee Dolomite: (a)—Tuberous and inclined columns with evenly banded microstructure and high-angle micro-unconformities. Thin section, S487, Myrtle Springs; (b) *B. burra* with minor pelletal laminae. Thin section, S150, Worumba; (c)—Subcylindrical columns with steeply domed, evenly banded laminae. Thin section, S302, West Mount Hut; (d)—Branching of narrow columns from the sides of a main wide column. Cut slab, S534, Dutton's Trough H.S. The specimen is taken from the biostrome shown in Fig. 13 (b); (e)—*B. burra* with predominantly pelletal laminae. Thin section, S496, Copley; (f)—Complex branching of columns from Arkaroola. Thin section, S457.

Fig. 15. (a)—*Baicalia burra* with finely silicified laminae. Thin section, natural size, S151, Worumba. Note the vertical tectonic dolomite veins; (b)—*B. burra*. Cut slab illustrating sub-parallel branching columns with high-angle micro-unconformities and banded lamination. S96, near Chintapanna Well, specimen collected by Mr. C. R. Dalgarno. Note the overgrown stromatolite fragment in the lower left quadrant, and the branch arising from an eroded column in the upper right; (c)—Indeterminate stromatolite, possibly *Baicalia burra*. Thin section, S322, near Carrieton; (d), (e) & (f)—*Boxonia melrosa*, Brighton Limestone equivalent, Melrose; (d)—Hand specimen illustrating longitudinal sections of columns; (e)—Thin section of holotype, S503. The lamination is indistinctly banded, and becomes diffuse in the wall zone; (f)—Thin section illustrating lamination and wall structure, S177, natural size. Note that the upper left and lower left corners of the thin section are composed of highly weathered rock.

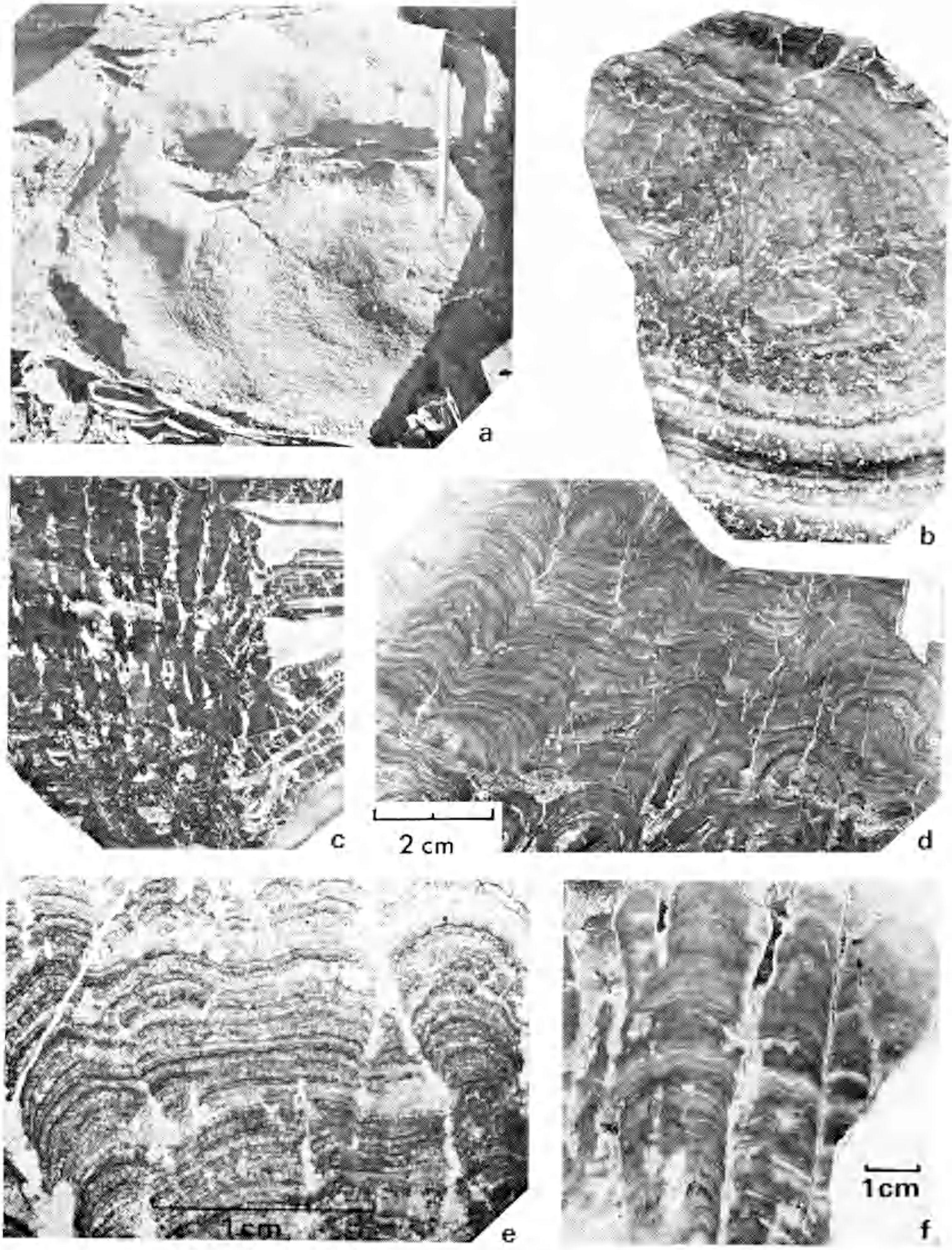

FIG. 10

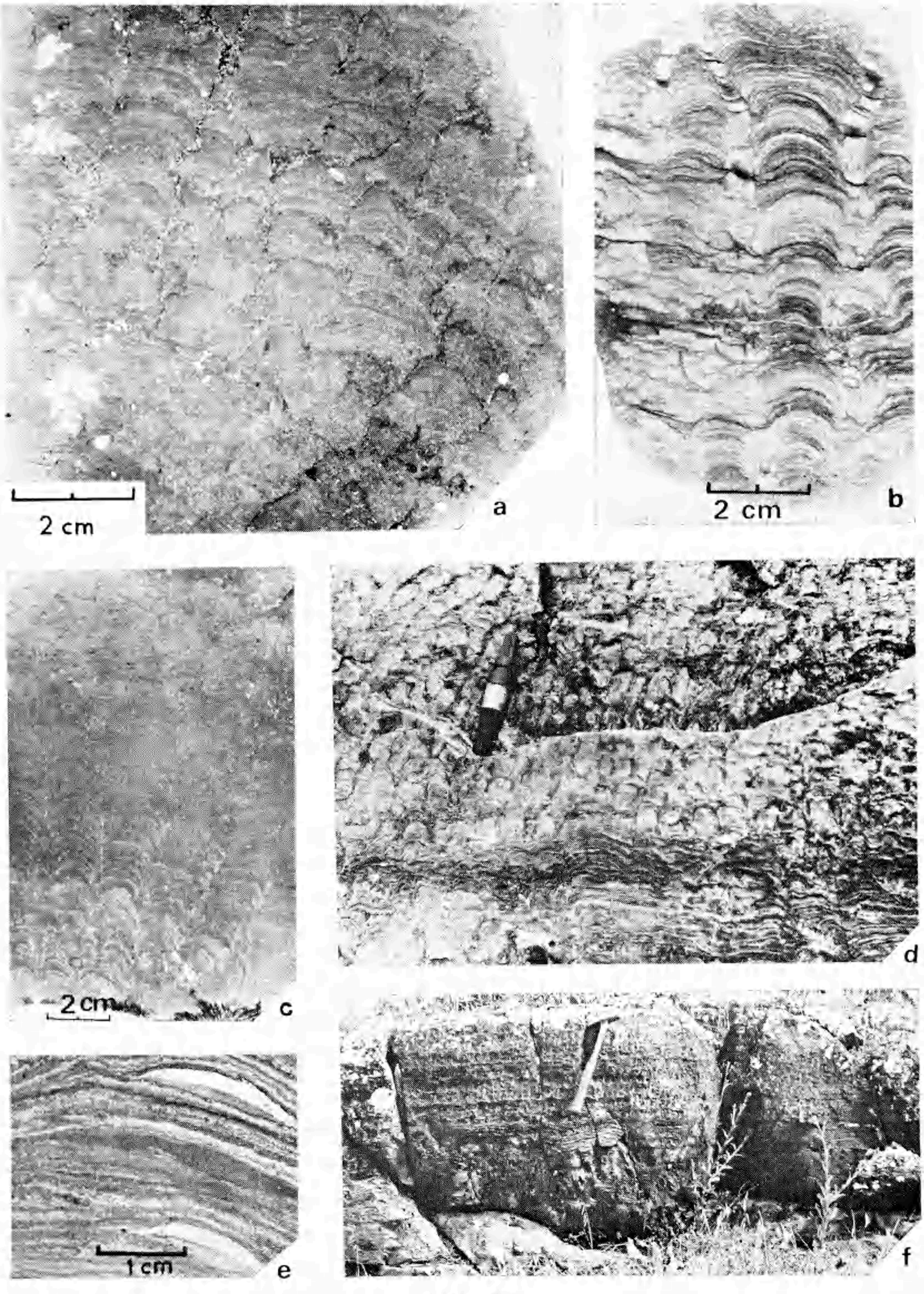

FIG. 11

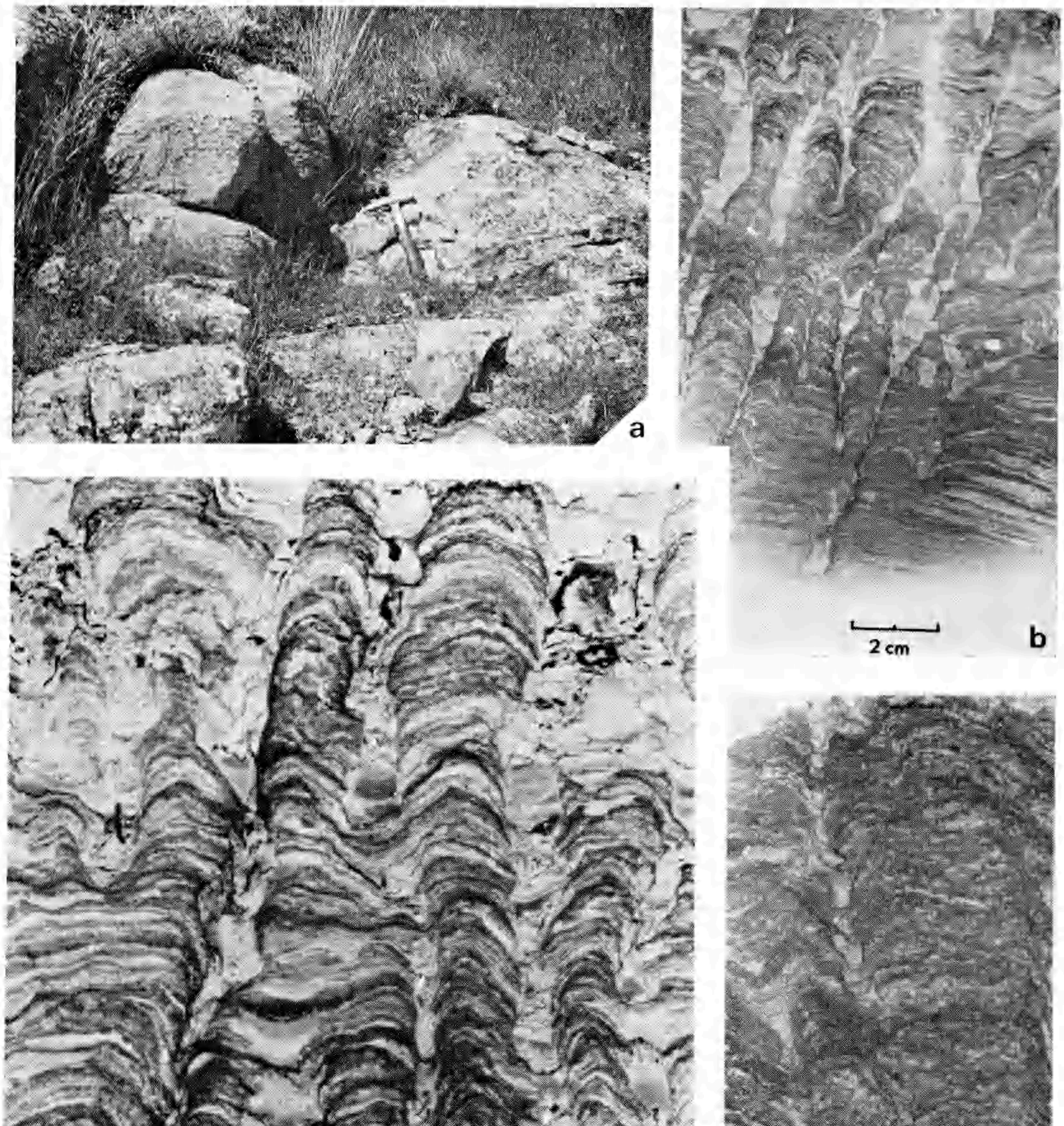

FIG. 12

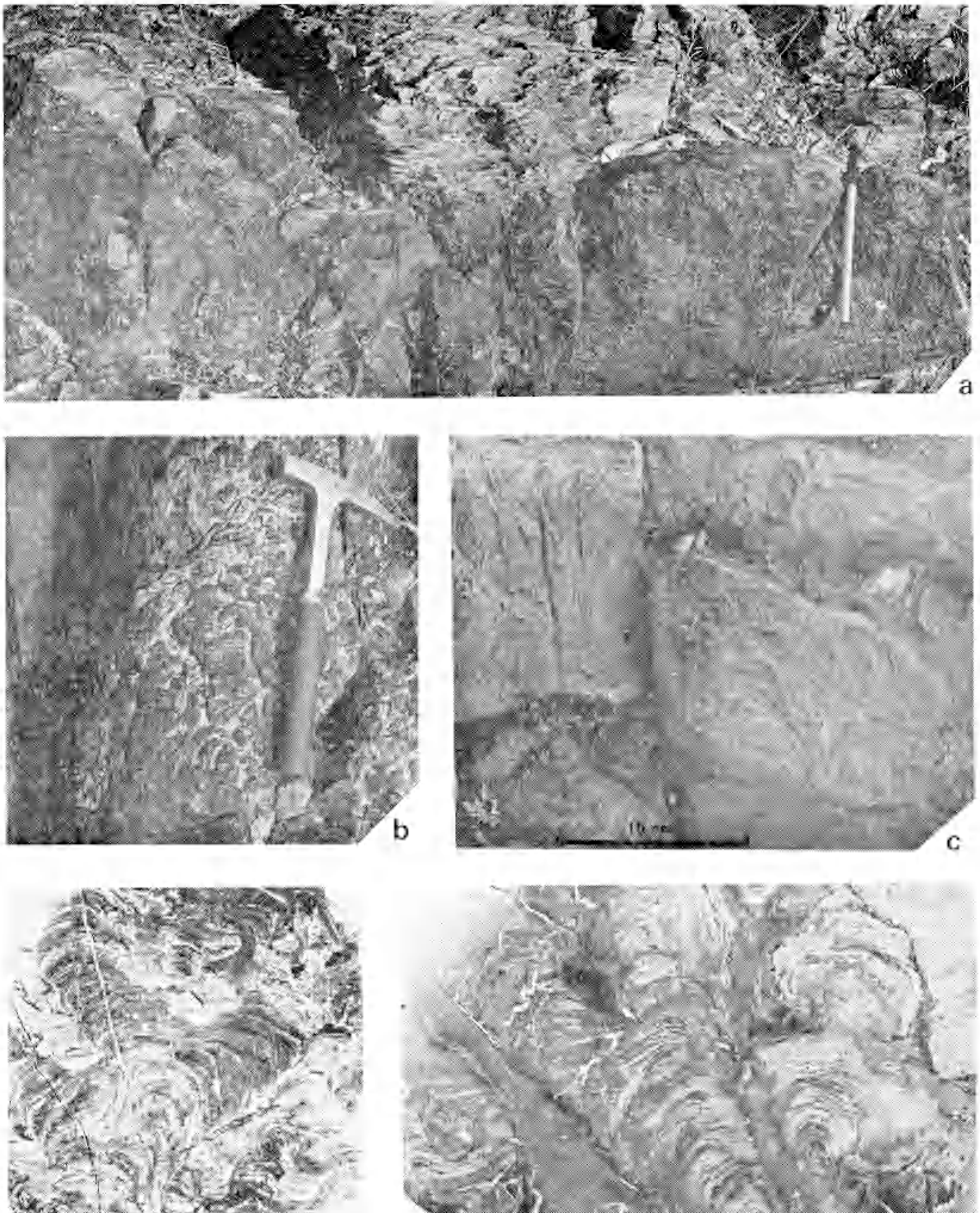

FIG. 13

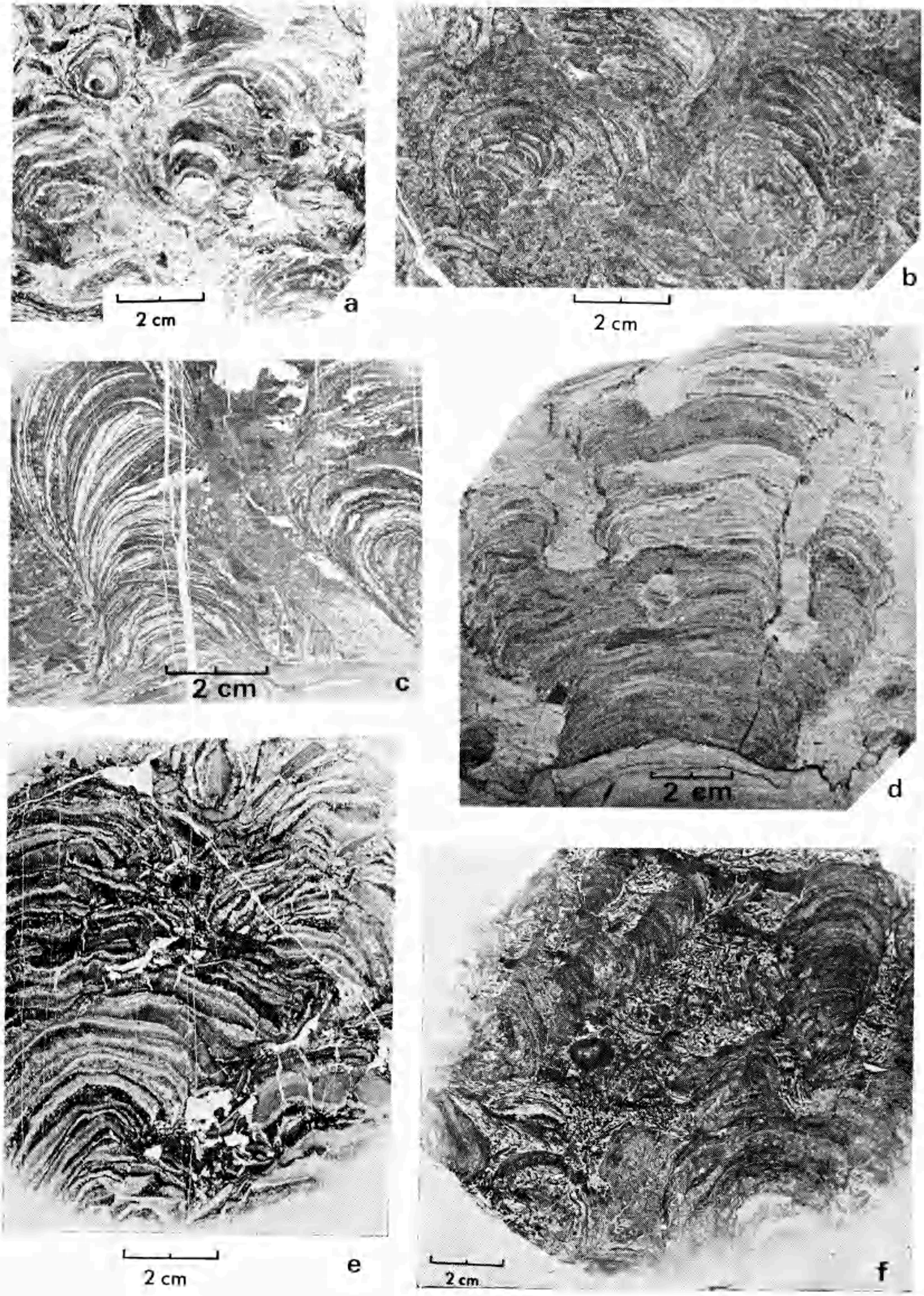

FIG. 14

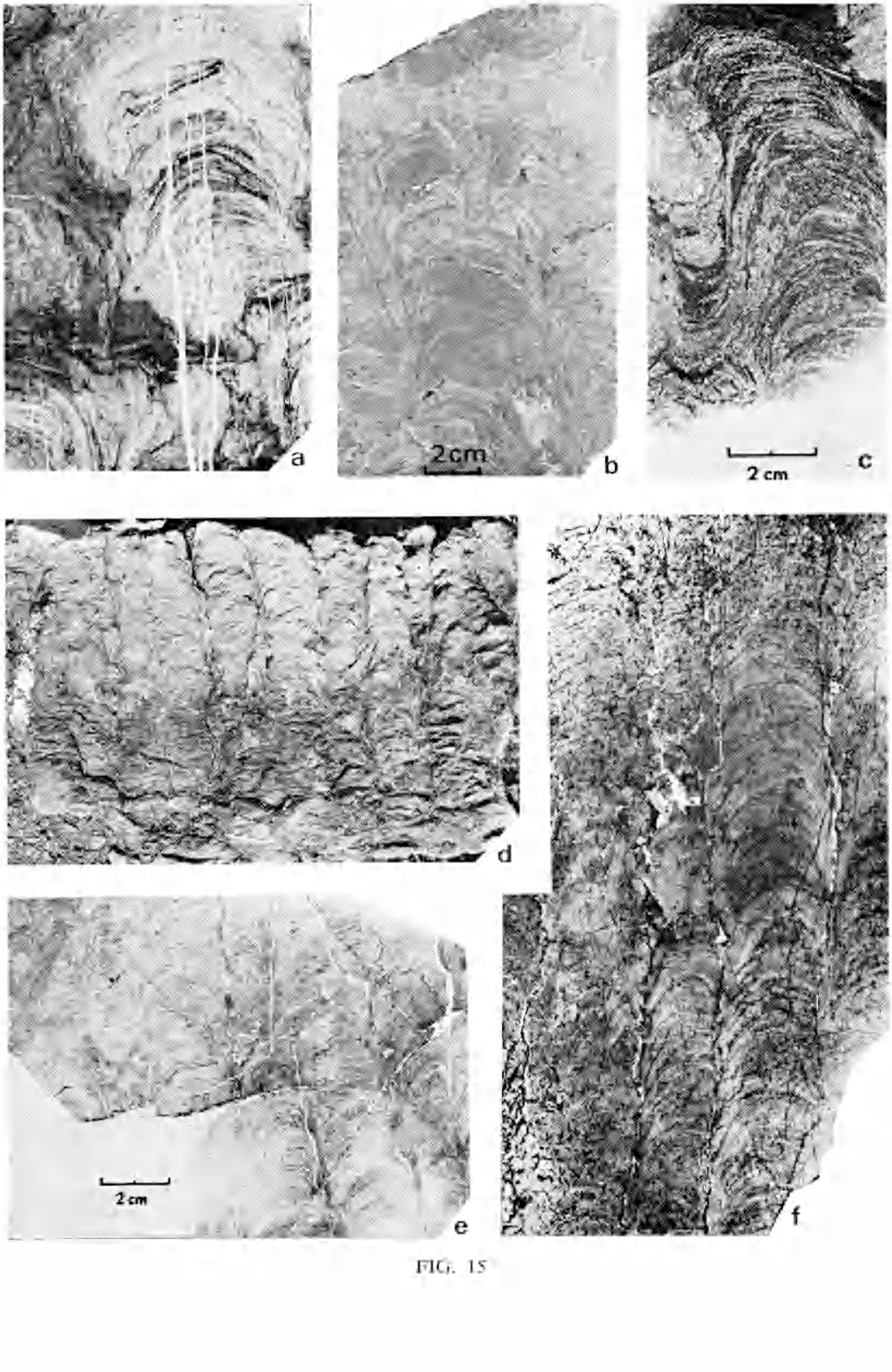

FIG. 15